NATIONAL MARINE FISHERIES SERVICE
SOUTHWEST FISHERIES CENTER
P.O. BOX 271
LA JOLLA, CA 92038

SOUTHWEST FISHERIES CENTER

APRIL 1989

EVALUATION OF THE PORT SAMPLING OF THE WET FISH FISHERY

By

Nancy C. H. Lo

Library
NOAA, National Marine Fisheries Service
SWFC Honolulu Laboratory F/SWC2
2570 Dole Street
Honolulu, HI 96822-2396

ADMINISTRATIVE REPORT LJ-89-10

This Administrative Report is issued as an informal document to ensure prompt dissemination of preliminary results, interim reports and special studies. We recommend that it not be abstracted or cited.

EVALUATION OF THE PORT SAMPLING OF THE WETFISH FISHERY

Nancy C. H. Lo

ABSTRACT

The port sampling procedure for estimating the age composition and species composition of the California wetfish fishery was evaluated based on 1982, 1985 and 1986 data. A simulation method was used to examine the bias and precision of the current sampling procedure for the age composition. The proportional to size sampling procedure produced reasonable age composition estimates for Pacific mackerel, but the bias of estimated age composition for jack mackerel was large. A weighted ratio estimator for the age composition was proposed for all species. Variance of the estimated species composition of the catch should be incorporated in the final computation of variance of age composition. Sample allocation for age composition and species composition was also investigated.

EXECUTIVE SUMMARY

Under a cooperative agreement with California Department of Fish and Game (CDFG) (6C-2019, June 15, 1987 - March 31, 1989) the Southwest Fisheries Center (SWFC) evaluated the port sampling procedure presently used by CDFG. The CDFG and the SWFC have a common interest in the age and species composition of the catch of the California wetfish fishery; CDFG is responsible for sampling the landings, but both agencies use the data for stock assessment and research.

Using data collected on age and species composition collected in 1982,1985,and 1986, we developed a simulation procedure to evaluate the current estimation procedures. Cost analyses were carried out to evaluate the optimal sample allocation for estimating age composition and species composition. The principle conclusions and recommendations were as follows:

Digitized by the Internet Archive
in 2025

https://archive.org/details/administrative-report-lj_1989-04_10

Age Composition

Best estimates for age composition: Currently, age composition is sampled taking 40 random samples per 5000 tons of the total cumulated catch. The simulation results indicate that when the current age composition is expressed in terms of the number of fish per gram, little bias exists for Pacific mackerel, but the bias is large for jack mackerel. If the number of fish per gram is weighted by the jack mackerel catch and adjusted by the total catch of the boat (hailed landing), the bias is reduced. The type of a ratio estimator used (number of fish per gram or number per sample, or either value with various weighting factors) did not affect the coefficient of variation (CV). However, the CV's differed among age groups. If a single ratio estimate is to be used for all species, then number of fish per gram weighted by catch is recommended in the future age composition computation.

Minimum Number of Samples Per Strata: The minimum number of samples (within a 5000-ton strata) needed to sample the age composition of Pacific mackerel and jack mackerel varied with their ages. Thirty samples of Pacific mackerel within a stratum provides estimates with the CV <0.5. For two-year-old jack mackerel a sample size of 30 guarantees a CV <0.3, but for one- year-olds the sample size needs to be much larger; a sample of 50 provides an estimate with a CV <2.0.

Comparison of sampling designs: Currently, the 40 samples within the 5000-ton strata are allocated to boats according to the weight of their catch (i.e. proportional to size; PPS). An alternate approach is to sample the boats with equal probability (simple random sample with replacement [SRS]). The SRS provided ratio estimates of age composition with small relative bias, but the CV under SRS and PPS were similar. For Pacific mackerel, the current method (number of fish per gram, unweighted) is the least biased method under either design. For jack mackerel, the number of fish per gram weighted by catch and total landings of all species (PPS) was the preferred method for estimation of age composition. The current sampling procedure (PPS) is acceptable for all species if the ratio estimator is weighted by catch and total landings.

Sample allocation for age composition: At the most two samples per boat are sufficient for Pacific mackerel, whereas for jack mackerel, no more than three samples per boat are necessary. Thus, no more than three samples per boat for age composition are needed.

Species Composition

Comparison between visual estimate and bucket estimate: The following two methods have been used to evaluate species composition of the catch: an estimate based on a visual inspection of the catch and one based on actual counts of each species in a bucket sample. Visual estimates and bucket estimates of species composition were similar; differences between the averages of two estimates were negligible. Although the visual method produces unbiased estimates of species composition, the visual estimate is more variable than the bucket estimate and the sampling coverage should be large to achieve a similar precision as the bucket estimates.

Minimum number of bucket samples per boat: A total of three bucket samples per boat is sufficient for estimating species composition. One or two samples are adequate if the cost of visiting a boat is more than ten times that of processing a sample.

Effect of variance of species composition on variance of age composition: Variance of the estimate of species composition of the catch has a significant effect on the variance of age composition of any species. Thus, the variance of the species composition should be incorporated in the final computation of variance of age composition.

Deciding when a species is to be sampled: Currently, jack mackerel and Pacific mackerel are sampled when they comprise 5% of the total catch of all species, while sardines are sampled when they comprise only 1% of the total catch. Using this procedure 1% of the total catch of jack mackerel and 1% of the total catch of Pacific mackerel are not sampled, but in sardines, 25% of the total catch is not sampled. If staffing is a problem and the species composition remains unchanged, the decision criterion for Pacific mackerel and jack mackerel could be raised from 5% to 10%. If raised to 10% no more than 3% of the landing would go unsampled.

CONTENTS

	Page
Introduction	1
Methods	3
Age composition	
1. Simulation procedures	3
2. Simple random sample with replacement	9
3. Sample allocation for age composition	9
Species composition	10
1. Comparison between visual estimates and bucket estimates	10
2. The sample allocation and the precision of bucket estimates	11
2.1 Minimum number of samples per boat sampled	11
2.2 Contribution of variance of species composition to the total variance of age composition	12
3. Sampling criterion for a specific species	13
Results	13
Age composition	
1. RB and CV of six ratio estimate under PPS	14
1.1 RB	14
A. Pacific mackerel	15
B. Jack mackerel	15
1.2 CV	16

2. Sample size determination within stratum base on CV 17
2.1 Pacific mackerel 17
2.2 Jack mackerel 17
3. RB and CV of age composition under SRS 18
3.1 RB of Pacific mackerel 18
3.2 RB of Jack mackerel 19
3.3 CV under SRS 20
3.4 Comparison of SRS and PPS 20
4. Sample allocation using cost analysis 20
Species composition 21
1. Difference between bucket and visual estimates 21
2. Sample allocation and the precision of bucket estimates 22
2.1 Minimum number of samples per boat sampled 22
2.2 Contribution of variance of species composition to the total variance of age composition 22
3. The sampling criterion for a specific species 23
Conclusions and recommendations 24
Acknowledgements 28
References 29
Tables
Figures

INTRODUCTION

Under the Cooperative Agreement(6C-2019), June 15, 1987 - March 31, 1989, between California department of Fish and Game (CDFG) and Southwest Fisheries Center (SWFC) for the port sampling project, the SWFC and the CDFG share a concern for the need to obtain sound estimates of species composition and age composition of mackerel and sardines in the mackerel fishery. The CDFG is responsible for collecting catch and other data from the California fisheries and for estimating species composition and age composition of the catch for stock assessment and quota monitoring. The SWFC is responsible for evaluating the sampling procedure for collecting mackerel and sardines, which was designed primarily for anchovy.

The specific objectives of this project are to evaluate

1. the current sampling procedure for **age composition.**

Currently, age composition is sampled by taking 40 random samples per 5000 tons of the total hailed cumulated catch. Boat loads are selected at random based on a list of 40 random numbers from 1 to 5000. A sample of a fixed weight is taken from a boat if the cumulated landing reaches or exceeds the next random number, and boats are sampled with replacement. Therefore it is possible to take more than one sample from a single boat. The probability of being sampled for any boat is proportional to its landing. This is called proportional to size sampling (PPS). This sampling

procedure was originally designed for the anchovy fishery (a single species fishery) and has been used for multiple species fishery. Once a boat is chosen, a species is sampled if the landings of the species exceed a certain percent of the total landings. The percent is 5% for either jack mackerel or Pacific mackerel, and 1% for sardines.

2. the sampling and estimation procedures of **species composition.**

Two estimates are available for species composition. One is the visual estimate (VE) taken by a biologist and the other is the bucket estimate (BE) taken by a warden. We are to compare VE and BE and examine the precision of the bucket estimate.

Age composition

The current computation procedure for age composition (in numbers) is the fraction of fish at age (in weight) from all samples, multiplied by the total landings divided by the mean weight of fish at age for each month. This procedure is equivalent to the ratio of the number of fish at age per gram in all samples multiplied by the total landings. In this report, we 1. investigated whether the estimates of age composition were appropriate under the current sampling scheme which was originally designed for a single species (Tomlinson 1971), by comparing the precision and relative bias of the current estimates (number of fish at age per gram) with five other types of ratio estimates by stratum, using a simulation model, 2. determined the minimum number of samples required within each stratum for a given coefficient of

variation (CV) and 3. investigated the proper sample allocation between number of boats sampled and number of samples per boat based on the cost of sampling.

Species composition

As mentioned earlier, two estimates are available for species composition. One is the bucket estimate (BE) by a warden, and the other is the visual estimate (VE) by a biologist. The former, a thorough sampling covers 36% of the boat loads. The latter, a crude eye examination, covers 75% of the boat loads. We compared the VE and the BE to see if the VE was as accurate and as precise as the BE, and examined the precision of the BE to determine sample allocation and the contribution of the variance of species composition to the variance of age composition.

METHODS

Age composition

1. Simulation procedures

The current estimates of age computation are based on a simple ratio estimate, the number of fish of age L per gram. This is a ratio estimate, easy to compute and understand. However, it is usually used when boats are sampled with equal probability. Based on the current sampling scheme, the probability that any boat is sampled is proportional to its hailed landing. This is referred to as proportional to size (PPS) sampling (Cochran 1977). To investigate the current estimates of age composition under the PPS, a computer simulation model was developed. This simulation model

takes all sampled boat loads in a year as a pseudo population from which boat loads were selected according to the current sampling procedure.

Data from sampled boat loads in 1982 and 1986 constitute two pseudo populations. Each pseudo population includes approximately 200 trips with information on month, hailed landings, actual total landings, landings by species based on species composition estimates, and fraction of age 1 to 6+ (age composition) for each species. Prior to 1989, sardine age composition was not available, although otoliths of sardines have been collected for age composition routinely since 1982 but just not aged. Thus, the analysis of age composition was restricted to Pacific mackerel (PM) and jack mackerel (JM) only. Sample weight (SWT) (gm) and average fish weight (AVGWT)(gm) were drawn from a normal distribution with mean and standard deviation (SD) computed from the actual observed data sets:

	1982				1986	
	PM		JM		PM	
	SWT	AVGWT	SWT	AVGWT	SWT	AVGWT
MEAN	4110	394	2352	199	4120	466
SD	120	130	61	68	200	93

In 1982, both Pacific mackerel and jack mackerel were sampled and aged. In 1986, although both species were sampled, only Pacific mackerel were aged. The 1982 pseudo population included 195 boat

loads with Pacific mackerel (some of them caught jack mackerel) and 179 boat loads with jack mackerel (some of them caught Pacific mackerel). The 1986 pseudo population included 219 boat loads with Pacific mackerel and 115 boat loads with jack mackerel (Table 1). In the actual sampling scheme, all boat loads within a cumulative 5000 tons belong to one stratum. Each stratum had 52 to 191 boat loads in 1982, and 71 to 139 boat loads in 1986 (Table 2). In the simulation model, because the number of boat loads in the pseudo population was small (Table 1), the cumulative tonnage for a stratum was reduced to 4000. The 4000 tons were chosen so that the total number of boat loads in each stratum would be similar to that in 1982 or 1986 (Table 2). And there were 3 strata in each pseudo population to mimic the actual stratified sampling scheme.

In the simulation (Fig. 1), six ratio estimates for age composition were computed (Table 3). These six ratios were chosen because each of them uses different information and is appropriate under different sampling schemes (see below). Although the ultimate goal of computing age composition was to estimate total number of fish at age (L) of species (k) ($Y_{L,k}$), in order to investigate the statistical properties of $Y_{L,k}$, it is sufficient to work on the ratio estimate because the total equals the ratio times a constant ($Y_{L,k} = r \times F$). The variance of the total is: $\text{var}(Y_{L,k}) = \text{var}(r) \times F^2$ where r is an estimate of the true ratio (R).

The following notations were used for ratio estimates of age composition.

Within a stratum, for the **ith boat load sampled**, i=1,...,n, from

a total of N boat loads and for the **jth sample within a boat load,** $j=1,..,\ m_i;\ m_i>=1$.

Σm_i: total number of samples (sample size)

y_{ijkL}: number of fish of species k and year class (or age) L

x_{ijk}: weight of the jth sample for species k

u_{ijk}: number of fish in a sample for species k

W_{ik}: estimated landing of species K for the ith boat load from either BE or VE.

$W_{0k} = \Sigma W_{ik}$: estimated total landings of species k for the stratum

$W_0 = \Sigma W_{0k}$: total landings for the stratum

$M_{ik} = W_{ik}/\bar{x}_{i.k}$: estimated total number of samples

$\bar{y}_{i.kL} = \Sigma y_{ijkL} / m_i$: average number of fish of year class L for species k

$\bar{x}_{i.k} = \Sigma x_{ijk} / m_i$: average sample weight for the species k

$M_{0k} = \Sigma M_{ik}$: total possible samples for species k for the stratum

R: a ratio, either number of fish of year class (age) L per unit weight (gram)(R(1)) or number of fish of year class (age) L per sample (R(2)).

F: a factor to raise the ratio R to a total, which can be either W_{0k} or M_{0k}

$Y_{L,k} = R \times F$:total number of fish of year class L for species k

Z_i:the hailed landings

$z_i = Z_i/\Sigma Z_i$: the probability of the ith boat being sampled.

The six ratio estimates are

$$r1 = \frac{\Sigma\Sigma y_{ijkL}}{\Sigma\Sigma x_{ijk}}$$

$$r2 = \frac{\Sigma M_{ik}(\Sigma y_{ijkL}/m_i)}{\Sigma M_{ik}}$$

$$r3 = \frac{\Sigma M_{ik}(\Sigma y_{ijkL}/m_i)}{\Sigma_i M_{ik}(\Sigma_j x_{ijk}/m_i)}$$

$$r4 = \frac{\frac{\Sigma m_i M_{ik}}{M_{0k}} \frac{1}{z_i} (\Sigma y_{ijkL}/m_i)}{\Sigma m_i}$$

$$r5 = \frac{\Sigma M_{ik}(\Sigma y_{ijkL}/m_i)/z_i}{\Sigma_i M_{ik}/z_i}$$

$$r6 = \frac{\Sigma M_{ik}(\Sigma y_{ijkL}/m_i)/z_i}{\Sigma_i M_{ik}(\Sigma x_{ijk}/m_i)/z_i}$$

The variance formulas for six ratio estimates are given in Table 3. The ratios, r1, r3, and r6, estimate the number of fish of age L per gram (R(1)), and r2, r4, and r5 estimate the number of fish of age L per sample, (R(2)). The ratio, r1 ,does not use landings information whereas the other five ratios do. In the simulation, both R(1) and R(2) were parameters which were computed directly from pseudo populations: R(1)= total number of fish of age L/ total catch(gm) and R(2) = total number of fish at age L / total number of possible samples, . The total number of fish of age L of species k ($Y_{L,k}$) can be estimated with any of the six ratios. The variance formula of $Y_{L,k}$ based on six ratios were also given.

The ratio estimate, r1, is the current estimate used for the

age composition computation, and r4 is used in the original sampling scheme (Tomlinson 1971). Ratios r1, r2 and r3 were based on simple random sampling (SRS) of boat loads and the other three ratio estimates (r4,r5,r6) were based on proportional to size sampling (PPS). In addition, simulation runs based on a simple random sample (SRS) of boat loads were also made for comparison purposes.

Simulation runs were made with different sample sizes (10 -50 per stratum) each with 1000 iterations. Means, standard errors(SE), and the coefficient of variation (CV) of each ratio estimate for each age group were computed for each stratum. The arithmetic average of 1000 ratios was used to estimate the mean (Er), and the standard error of a ratio estimate (se(r) was computed as $[\Sigma(r-Er)^2/1000]^{0.5}$. The mean of 1000 ratios (Er) was compared with the true values (R= R(1) or R(2)) to assess the relative bias(RB): RB= (Er - R)/R.

The coefficient of variation (CV=se(r)/Er) of the ratio estimates was used to assess the precision of the estimates. The estimate with the least bias and lowest CV over all age groups is considered as the best estimate. For a given CV, a minimum sample size was determined for each age group from the simulation results.

The RB and CV of each ratio estimate for all age groups were computed for each 4000-ton stratum (stratum estimates) as well as for the entire year (yearly estimates). As the age composition is the primary input to the cohort analysis, the estimate within stratum is more important than the yearly estimate.

2. Simple random sample with replacement (SRS)

Under the simple random sample with replacement(SRS) scheme, each boat has an equal chance of being sampled and the sampled boats are not excluded from being sampled again. This SRS is a simple sampling method and was included in this study for comparison purposes, because three of the ratio estimates (r1-r3) were derived based on SRS.

We chose 100 boats as a stratum to be compatible with PPS (Table 2). One thousand computer runs were made for sample sizes 10,20,.., 50 for 1982 and 1986, respectively. The CV and RB of three ratio estimates (r1 - r3) were obtained for Pacific mackerel and jack mackerel. Because boats were sampled with replacement, the actual number of distinct boats sampled within a stratum was smaller than the aimed sample size.

3.Sample allocation for age composition

Under the current sampling procedure (PPS), boats with large hailed landings may be sampled more than once. In other words more than one sample ($m_i>1$) may be taken from a boat. We conducted a cost analysis on each age group to determine the minimum number of samples per boat, i.e., the optimum allocation of samples among the sampled boats. The number of samples for each sampled boat and number of boats sampled depends on the cost of sampling and the variance of age composition between the boats (s1) and within the boat (s2). The cost includes the cost (c1) of visiting a boat and

the cost (c2) of processing each sample. For a given amount of money which is distributed between all sampled boats (n) and samples per boat (m), the best allocation of samples is one that yields a minimum variance of the age composition.

The formula for the variance of the estimated age composition is a function of N,F,s1,s2, n and m:

$var(r) = f(N, F, s1, s2, n, m)$

$\tilde{-} [(N^2/(F^2 n)] [s1^2 + s2^2/m]$

where $s1^2$ is variance among boats, $s2^2$ is variance within boat, $m=\Sigma m_i/n$, N is number of boat and F is a multiplier (Table 3).

The variance of r6 was used for var(r). The cost function can be written as

$c= n \times c1 + m \times n \times c2.$

To minimize var(r) subject to the above cost function, Cochran (1977) has the optimum number of samples, $m^* = (c1/c2)^{0.5} \times s2/s1$ and the number of boats $n = c/(c1+m^* \times c2)$.

The optimum number m* was computed for combinations of c1/c2 and c/c2.

Species composition

1. Comparison between visual estimates (VE) and bucket estimates (BE).

Both visual and bucket estimates of species composition were expressed in percent for each boat load sampled. The comparison of VE and BE was made based on 1985 and 1986 data. Boat loads with

data from both bucket and visual estimates were included in the analysis, except those boat loads with only one species. A paired t test was employed to test if there is any bias in visual estimates. A regression analysis was used to investigate the predictability from the visual estimates to bucket estimates. The analysis was carried out for Pacific mackerel and jack mackerel separately.

2. The sample allocation and the precision of bucket estimates

Although both VE and BE were used for species composition, in this section we investigated some statistical properties of bucket estimates. The current procedure of computing the total landings of a species (W0k) is

$$W_{0k} = W_0 \left[\sum_i W_i \left(\sum_j x_{ijk} / \sum_j \sum_k x_{ijk}\right)\right] / \Sigma W_i$$
$$\simeq W_0 [\Sigma M_i \bar{x}_{i.k} / \Sigma M_i \bar{x}_{i..}]$$

where W_0 is the total catch and $= \sum_k W_{0k}$, W_i is the total catch for the ith boat, M_i is the total number of possible buckets for the ith boat, and x_{ijkL} is fish weight in the sample. Thus the total landings of a species are computed based on r3-type ratio estimate (Table 3). In this report, the landings of a species (W_{0k}) were computed by stratum, although in practice, they were computed monthly.

2.1. Minimum number of samples per boat sampled.

The same procedure of sample allocation for age composition was used here for species composition. The ratio (r3) was used to compute the species composition. The variance formula for r3 is given in Table 3. The optimum number m* was computed for combinations of c1/c2 and c/c2.

2.2. Contribution of variance of species composition to the total variance of age composition.

The final estimate of number of fish of age L of species K is the product of the fraction of fish at age L ($r_{L,k}$) and the estimated total catch of that species (W_{0k}):

$$Y_{L,k} = r_{L,k} \times W_{0k}$$

with variance

$$var(Y_{L,k}) = var(r_{L,k}) \times (EW_{0k})^2 + var(W_{0k}) \times (Er_{L,k})^2$$

where $var(r_{L,k})$ and $var(W_{0k})$ are function of number of boats visited (n) and number of samples per boat (m). The symbol E* represents the average of the variable *. If all the fish in the catch were identified (for the species composition) ,the $var(W_{0k}) = 0$, and the variance of $Y_{L,k}$,say $var_0(Y_{L,k}) = var(r_{L,k}) \times (EW_{0k})^2$. The ratio of variance of age composition ($var(Y_{L,k})$ to that without variance of species composition($var_0(Y_{L,k})$) can be written as

$$var(Y_{L,k})/var_0(Y_{L,k}) = 1 + [CV(W_{0k}) / CV(r_{L,k})]^2.$$

where the CVs are also functions of number of boats visited (n) (the within boat variance was computed from 1986 data). The last term in the above equation measures the additional variation of age composition contributed by the species composition and changes with sample size. The variance ratio, var/var_0, is close to one if

the $CV(W_{0k})$ is small relative to the $CV(r_{L,k})$. Data from 1986 were used to evaluate this 'variance ratio' for ratios of the number of boats visited (n1) (by a warden) for species composition to the number of boats visited (n2) (by a biologist) for age composition , i.e. n1/n2.

3. Sampling criterion for a specific species.

Pacific mackerel is sampled if the landings of Pacific mackerel exceed 5% of the total landings. The same percentage is applied to jack mackerel. For sardines, the minimum landings are 1% of the total landings.

Using this criterion, certain landings are not sampled for a species because the species is too small a portion of the catch. We assembled the landings data of 1985 and 1986 to estimate the percentage of the landings contributed by boat loads with various species composition.

RESULTS

Age composition

The simulation method was used to estimate the following: 1) the relative bias (RB) and the coefficient of variation (CV) of each of the 6 ratio estimates under the current sampling scheme, PPS ; 2) the minimum sample size for the most accurate and most precise ratio estimate; and 3) the RB and CV under SRS of boat loads compared with PPS. A cost analysis was conducted to determine the minimum number of samples per boat.

1. RB and CV of six ratio estimates under proportional to size sampling(PPS)

Both the RB and CV of six ratio estimates should be compared to determine the least biased and most precise estimate. Because the CVs were similar among six ratios, only the RB was used to select the best estimate for age composition, and the CV was used to determine the minimum sample size within a stratum. The 1982 data contained both Pacific mackerel and jack mackerel age composition, thus the results from 1982 were used to select the best estimate. Although the RBs of Pacific mackerel from 1986 data were not used in comparing six ratio estimates, they were much smaller than the RB from 1982 data (Fig 2). The CV results based on 1986 for Pacific mackerel and 1982 jack mackerel were used for sample size determination.

1.1 RB: All six ratio estimates were biased, therefore the best ratio estimate was the one that had the smallest relative bias (RB). For the sample sizes considered here (10-50 per stratum), the RB did not decrease with the sample size in some cases. Without loss of generality, the RBs of 6 ratio estimates for each age group for a fixed sample size, say 40, were compared to determine the least biased estimate. The simulation results of 1982 indicates that r1 (or r6) is the least biased for Pacific mackerel, and r6 (or r5) for jack mackerel.The following are analyses for each species.

A. Pacific Mackerel

Based on the simulation results of 1982(Fig. 2a), for the yearly estimates over all the age groups, the ratio r1 has the least RB ranging from -0.1 (one-year-olds) to 0.43 (five-year-olds) when 40 samples were taken within a stratum. Among all age groups, two-year-olds (80 year class) were the least biased with RB(r1) =-0.08. The within-stratum analysis shows that the least biased are r1: In stratum 1, RB(r1) ranged from -0.27 (six-year-olds) to -0.03 (five-year-olds), in stratum 2, RB(r1) ranged from -0.18 (one-year-olds) to 0.22 (five-year-olds), and in stratum 3, RB(r1) ranged from -0.05 (one-year-olds) to 0.9 (six-year-olds). Thus, the current ratio estimate (r1) is the least biased estimate.

The RBs of the six ratio estimates from 1986 were smaller than the RBs in 1982. The differences of RBs among the six ratio estimates in 1986 were also smaller than 1982. The 1986 data again indicated that the current estimator (r1) was still the least biased estimate among the six ratio estimators with the RB within stratum ranging from -0.3 to 0.15 (Fig 2b).

B. Jack mackerel

For the yearly estimates, and all the age groups with sample size equal to 40, the ratio r6 has the least RB ranging from -0.3 (one-year-olds) to 0.9 (six-year-olds) (Fig. 3). Among all age groups, two-year-olds (80 year class) were the least biased with RB (r6) =-0.08. The within-stratum analysis shows that the least biased are r6 for all strata: in stratum 1, the RB(r6) ranged from -0.5 (one-year-olds) to 0.9 (six-year-olds), in stratum 2, RB

(r6) ranged from -0.3 (one-year-olds) to 1.2 (five-year- old). In stratum 3, RB(r6) ranged from -0.25 (one-year-olds) to 0.4 (three-year-olds). The RB(r1) was in general higher than the RB(r6) for the yearly estimate. However, the RB(r1) was even higher for stratum estimates. In stratum 2, for example, the RB(r1) for the five-year-olds was as high as 3.6. Among the six estimates, the degree of bias, in the ascending order, was: r6 and r5, r2 and r3 , r1 and r4. Recall that ratio r1 does not include landing data whereas the other five ratios do. Thus including landings data in the ratio estimates under PPS reduces the bias.

1.2. CV: Similar to RB, the CVs for the yearly estimates and the estimates by stratum were computed for each age group based on the 1982 and 1986 data for various sample sizes (10-50) within stratum. For Pacific mackerel, the CV's of estimates in 1986 were considerably lower than those in 1982, thus results based on 1986 were analyzed to select the estimates of the least CV and sample size determination(Fig. 4a and 4b). For jack mackerel, 1982 simulation runs were used. The results from both years indicated that the CVs of six ratios are similar for any combination of species, age group and a given sample size (Fig. 4 and 5). Thus CVs were used only for sample size determination and were not used for choosing the best estimate. For the determination of minimum sample size for each species over all age groups, CV(r6) were compared for various sample sizes.

2. Sample size determination within stratum based on CV

Although CVs were similar among estimates, CVs were different among age groups. In the following paragraphs, the CV(r6) for a sample size of 40 is used to describe the ranges of CV among age groups within stratum and the minimum sample sizes are recommended for each species by stratum.

2.1.Pacific mackerel:

The CV values for r6 were low (Fig. 6). With a sample size of 40, for the yearly estimates, among the age groups, the five-year-olds had the lowest CV (0.06) and the one-year-olds had the highest CV (0.13). The CV's for stratum estimates were similar for a given age group and a given sample size among strata. In stratum 1 with no one-year-olds, for a sample of size 40 in a stratum, the CV ranged from 0.06 (five-year-olds) to 0.34 (two-year-olds). In stratum 2 the CV ranged from 0.09 (five-year-olds) to 0.35 (one-year-olds). In stratum 3 the CV ranged from 0.15 (2, 1, and five-year-olds) to 0.32 (three-year-olds). Comparing the CV(r6) for sample sizes 10-50, a minimum sample size of 30 within stratum provides estimates of CV < 0.4 for any stratum (Fig. 6). When the sample size increases to 50, the CV will be reduced to less than 0.3.

2.2. Jack mackerel

The CV values for jack mackerel in general were higher than those of Pacific mackerel. For the yearly estimates, unlike Pacific mackerel whose five-year-olds had the lowest CV, the two-year-olds

of jack mackerel had the lowest CV (0.08). Similarly to Pacific mackerel, the one-year-olds had the highest CV (0.64) (Fig. 7). The CV's for stratum estimates were different for some age groups. In stratum 1, for a sample of size 40 in a stratum, the CV ranged from 0.14 (two-year-olds) to 0.64 (one-year-olds). In stratum 2 the CV ranged from 0.1 (two-year-olds) to 1.8 (six-year-olds). In stratum 3 the CV ranged from 0.22 (two-year-olds) to 0.9 (one-year-olds). The CVs of ratios in stratum 2 were the highest, followed by those in stratum 1 and stratum 3. Comparing the CV(r6) for sample sizes 10 -50, the minimum sample size varies with the age group (Fig. 7). For two-year-olds, a sample of size 30 guarantees CV < 0.3. However, for the one-year-olds, the sample size needs to be greater than 50 within stratum to provide estimates of CV < 2.0. If the CV of jack mackerel follows the trend of Pacific mackerel, the CV should decrease in recent years, as the sampling technique improves.

3. RB and CV of age composition under SRS

The main purpose of including SRS in this study is to compare SRS with the PPS. We presented, for sample size 40, the CVs and RBs of three ratio estimates (r1-r3) for all age groups by stratum using 1982 data under SRS(Fig. 8-11). These CVs and RBs under SRS were compared with those under PPS (Fig. 2 - 4).

3.1 RB of Pacific mackerel.

For the yearly estimates over all the age groups, the ratio

r1 has the least RB, ranging from 0.05 (one-year-olds) to 0.44 (five-year-olds) when 40 samples were taken within a stratum (Fig. 8). The within-stratum analysis shows that the least biased is r1: in stratum 1, RB(r1) ranged from -0.27 (six-year-olds) to -0.02 (one-year-olds); in stratum 2, RB(r1) ranged from 0.02 (two-year-olds) to 0.52 (five-year-olds); and in stratum 3 RB(r1) ranged from -0.05 (one-year-olds) to 0.59 (five-year-olds). Thus, the current ratio estimate (r1) is the least biased estimate under SRS and the RB(r1) under SRS were smaller than PPS (Fig. 2 and 3). Thus, if the current ratio estimate (r1) is to be continued, the SRS may be another alternative for Pacific mackerel.

3.2. RB of jack mackerel

For the yearly estimates, and all the age groups with sample size equal to 40, the ratio r3 has the least RB ranging from -0.3 (one-year-olds) to 0.98 (six-year-olds)(Fig. 9). Among all age groups, two-year-olds (80 year class) were the least biased with RB(r3) =-0.08. The within-stratum analysis shows that the least biased are r3 for all strata for most age groups: in stratum 1, the RB(r3) ranged from -0.39 (one-year-olds) to 0.9 (six-year-olds), in stratum 2, RB (r3) ranged from -0.3 (one-year-olds) to 1.2 (five-year-olds). In stratum 3, RB(r3) ranged from -0.2 (one-year-olds) to 0.5 (three-year-olds). The RB(r1) was in general higher than the RB(r3) for the yearly estimate. Unlike PPS, the difference between the RB(r1) and the other two was not great for stratum estimates. The RB(r3) under SRS were similar to the RB(r6) under PPS(Fig. 3), both being smaller than RB(r1).

3.3 CV under SRS

Similar to the results of CV under PPS, the difference among the CV of three ratio estimates was negligible for both species, yet the difference of CV among age groups was larger under SRS (Fig. 10 and 11). There seems to be little difference in CV between SRS and PPS within an age group. Thus, the CVs were not used in choosing between SRS and PPS (Fig. 4,5,10 and 11).

3.4 Comparison of SRS and PPS

The SRS provided ratio estimates of small RBs. Yet, the CVs under SRS and PPS were similar. For Pacific mackerel, the current estimate, r1, is the best choice under either sampling scheme, followed by r6 under PPS. For jack mackerel, r6 under PPS is the best choice, followed by r3 under SRS.

4. Sample allocation using cost analysis

The sample allocation was computed using the variance formula for r6 for Pacific mackerel and jack mackerel separately for each stratum using 1982 data (Table 4). Because the variance differs among age groups, the sample allocation differs among age groups. The current cost of visiting a boat (c1) is $32 and the cost of processing a sample is $30. Thus the ratio of c1/c2 is close to 1. For Pacific mackerel, the 1986 data indicated that at most 2 samples per boat are needed. For jack mackerel, the 1982 data indicated that 1-2 samples are needed for most year classes, but, for the 80 year class,maximum of 6 samples are necessary. If the cost is a problem, 3 samples per boat would be sufficient for most of year classes, and more boats can be sampled.

Species composition

1. Difference between bucket and visual estimates.

Little difference was detectable between the averages of BE and VE for both Pacific mackerel and jack mackerel for 1985 and 1986 (Table 5). Both BE and VE are estimates of the fraction of catch being a particular species. The mean difference of VE and BE is less than 2% for both species. In other words, the average of VE is within the average of BE + or - 2%. Thus we conclude that little bias exists in the VE compared to BE.

The regression analyses indicated that the coefficient of determination (r^2) of visual and bucket estimates was between 0.68 to 0.80 for both jack mackerel and Pacific mackerel in 1985-86. This means that the predictability of VE is about 0.70. We further listed the mean and standard deviation of VE corresponding to each of 10 equal intervals of BE in percent, i.e. 0 to 10, 11 to 20,... 90 to 100 for both species (Table 5). The mean percent in each interval was similar between bucket and visual estimates. Yet the standard deviation of VE was large. The VE was least precise for small catch of Pacific mackerel and for large catch of jack mackerel. For Pacific mackerel, the largest standard deviation was 26 in the interval of 21 to 30 of BE in 1985 and 33 in the interval of 11 to 20 of BE in 1986. For jack mackerel, the standard deviations were evenly distributed among intervals with the largest value of 26 in the interval of 71 to 80 of BE in 1985, yet in 1986, the largest standard deviation was 33 in the interval of 81 to 90 of BE. Thus we concluded that although the VE is unbiased

compared to BE ,but the VE was less precise than the BE.

2. Sample allocation and the precision of bucket estimates.

2.1. Minimum number of samples per boat sampled.

The number of samples (m) per boat and number of boats(n) were computed for different combination of cost ratio: c1/c2= 0.5,1.0,..,16.0, and c/c2 = 50 and 100 by stratum. The ratio c1/c2 measures the cost of visiting a boat relative to processing a sample. The ratio c/c2 is the total amount of money available relative to c2. We only present the result for Pacific mackerel because the results for the other two species were similar. As most of the catch included only two species, the variance of the fraction of a species is equal to that of the other species, because p + q =1, var(p) = var(1-q) = var(q) where p = fraction of the catch being one species and q being the other. The results indicated that the variance ($s2^2$) within a boat was small compared to the variance ($s1^2$) among boats : $(s2/s1)^2$ ranged from 0.05 to 0.54 among strata, thus the within-boat variance is at most 0.54 that of among-boat variance. When the cost of visiting boat is high, say 16 times that of processing a sample, 3 samples per boat is sufficient (Table 6). The number of boat (n) was also given.

2.2. Contribution of variance of species composition to the total variance of age composition.

To evaluate the contribution of variance of species composition to the total variance of age composition, We computed

the quantity, $ra(CV) = [CV(W_{0k}) / CV(r_{L,k})]^2$ for each year class by stratum (4000 ton). Recall

$$var(Y_{L,k})/var_0(Y_{L,k}) = 1 + [CV(W_{0k}) / CV(r_{L,k})]^2 = 1 + ra(CV)$$

where $CV(W_{0k})$ is the CV of species composition computed according to variance formula for r3 (Table 3), and $CV(r_{L,k})$ is the CV of age composition (r6) obtained from the simulation. When the number of boats sampled for age composition (n2) and species composition (n1) are identical, ra(CV) (or CV1/CV2 in Table 7) in general were high: ranging from 0.4 to 3.88 in stratum 1, 0.42 to 8.71 in stratum 2, and 0.69 to 3.37 in stratum 3 (Table 7). The ratio ra(CV) decreases as the sample size (n1) for the species composition increases. To achieve a certain level of ra(CV), 0.05, 0.1, 0.3 and 0.5, the ratio of sample size for species composition (n1) to that for age composition (n2) was also given (Table 7). The ratio (n2/n1) varies among age groups. The variance of species composition has greater effect on the variance of the age group that has smaller variance than the variance of the age group with large variance , e.g. the 81 year class compared to the 85 year class (Table 7). Thus the variance of species composition is a significant addition to the variance of age composition when the species composition is estimated from sample observations, and should be included in the computation of the final variance of age composition.

3. The sampling criterion for a specific species.

The distribution of landings for different species composition

(<=4%,5-10%,...,50+%) was provided for each of three species for 1985 and 1986 (Table 8) based on bucket and visual estimates.

Based on 1986 catch data and species composition from bucket estimates, 0.03% of the landings of Pacific mackerel were contributed by boat loads with Pacific mackerel <5% of the catch, 1.1% of the landings by boat loads with Pacific mackerel <11% of the catch, and 86.5% of the landings of Pacific mackerel came from boat loads with Pacific mackerel >50% of the catch. For jack mackerel, 0.84% of the landings of jack mackerel were contributed by boat loads with jack mackerel <5% of the catch, 3.2% of the landings by boat loads with jack mackerel <11% of the catch, and 53.8% of the landings of jack mackerel came from boat loads with jack mackerel >50%. For sardines, 25.6% of landings of sardines were contributed by boat loads with sardines <5% of the catch, 49.2% of the landings by boat loads with sardines <11% of the catch and no boat loads had sardines >50% of the catch.

The results from 1985 are similar to 1986 and the analysis based on visual estimates gave similar results as did bucket estimates (Table 8).

CONCLUSIONS AND RECOMMENDATIONS

Age composition

Best estimates for age composition

The simulation results indicate that under the current sampling procedure where the boats are selected based on their

hailed landings, r1 (or r6) is the least biased for Pacific mackerel, and r6(or r5) is the least biased for jack mackerel. The relative bias of r1 for jack mackerel can be severe for the stratum estimates. The CVs of 6 ratio estimates were similar, although the CVs were different among age groups. If one single ratio estimate is to be used for all species, then r6 is recommended in the future age composition computation.

Sample size determination within stratum based on CV

The CVs (r6) from the 1986 simulation results were used for Pacific mackerel. The minimum sample size varies with age groups. For Pacific mackerel, a sample size of 30 within each stratum provides estimates of any age group with CV <0.5. The CVs(r6) from the 1982 simulation results were used for jack mackerel. The minimum sample size varies with age groups. For two-year-olds, a sample size 30 guarantees a CV <0.3. However, for one-year-olds, the sample size needs to be greater than 50 within stratum to provide estimates of CV <2.0.

Comparison between PPS and SRS

The SRS provided ratio estimates of age composition with small RB. Yet the CV under SRS and PPS were similar. For Pacific mackerel, the current estimate, r1, is the least biased under either sampling scheme. For jack mackerel, r6 under PPS is the best choice, followed by r3 under SRS. For estimating the age composition of three species, the current sampling procedure (PPS) is acceptable if r6 is used for minor species, in particular, when

the species composition varies between boats. Because the SRS and PPS yield estimates of similar RB and CV, the PPS can be continued.

Sample allocation based on cost analysis

For Pacific mackerel, at most 2 samples per boat are sufficient, whereas for jack mackerel, at most 3 samples per boat are necessary. Because the analysis on jack mackerel was based on 1982 data, the variance ratio of within boat and among boat may be overestimated. Nevertheless, there is no need to take more than 3 samples per boat, and thus more boats can be sampled.

Species composition

Comparison between VE and BE

The difference between the averages of visual estimates and bucket estimates is minimal. However, the visual estimates have large variation for large catch of jack mackerel and small catch of Pacific mackerel. The minimum number of boat loads for VE is not computed and should be investigated in the future.

Minimum number of samples per boat

For estimating species composition from bucket estimates, a total of 3 samples per boat is sufficient, if the cost of visiting a boat is high (e.g. more than 10 times cost of processing a sample), otherwise one or two samples are adequate.

Contribution of variance of species composition to the total variance of age composition

The contribution of variance of species composition to the total variance of age composition is significant, and the variance of the species composition should be incorporated in the final

computation of variance of age composition.

The criterion of sampling a species for sampled boat

The current criterion of sampling a particular species once a boat is chosen misses less than 1% of catch for Pacific mackerel and jack mackerel. For sardines, if samples were taken from boats with >= 5%, then 25% of the catch will be missed. If staffing is a problem, and the species composition remains unchanged, the percent for Pacific mackerel and jack mackerel may be raised from 5% to 10%. Then, at most, 3% of the landings will be missed.

ACKNOWLEDGEMENTS

The author thanks Carlos Vedovato of La Jolla Laboratory, SWFC, Donna Mallicoate of Pacific Fisheries Environmental Group for data assemblage and programming the simulation, C. J. Park of San Diego State university for discussions on statistical methodologies during the projection , Patricia Wolf of CDFG for providing the data sets ,cost computation, and reading the draft, and Steven Torres of CDFG for reading the draft.

REFERENCES

Cochran W.G. 1977. Sampling techniques. Third addition. John Wiley & Sons. 428 p.

Tomlinson, P.K. 1971. Some sampling problems in fishery work. Biometrics 27:631-641.

Table 1. Total number of boats (N) in each stratum (4000 tons) for pseudo populations of 1982 and 1986 used in the simulation. PM is Pacific mackerel, JM is jack mackerel.

1982

stratum	species	N	Hailed landings (tons)
1	PM	90	4005
	JM	82	3580
	Total	90	
2	PM	66	1950
	JM	87	2768
	Total	130	
3	PM	39	1670
	JM	10	305
	Total	45	
Overall	PM	195	7625
	JM	179	6653
	Total	265	

1986

stratum	species	N	Hailed landings (tons)
1	PM	74	3935
	JM	62	3415
	Total	75	
2	PM	66	3875
	JM	33	1795
	Total	71	
3	PM	79	3920
	JM	20	1275
	Total	80	
Overall	PM	219	11731
	JM	115	6485
	Total	226	

Table 2. Total number of boats (N), number of boats sampled for Pacific mackerel (n(PM)), number of boats sampled for Jack mackerel(n(JM)), and total number of boats sampled (n) by stratum for 1982 and 1986 excluding boats without information on landings. n < or = n(PM) +n(JM) because some boats caught both species.

1982

Stratum	N	n(PM)	n(JM)	n
1	52	11	6	11
2	140	35	33	35
3	128	31	27	31
4	191	33	34	35
5	164	8	26	34
6	174	17	23	34
7	177	13	20	31
8	151	32	5	35
total	1177	199	180	269

1986

Stratum	N	n(PM)	n(JM)	n
1	110	30	19	31
2	113	33	32	33
3	112	30	26	30
4	139	28	11	32
5	88	25	6	26
6	121	34	8	34
7	125	28	5	29
8	71	14	7	14
total	879	222	114	229

Table 3. Six ratio estimates for computing the fraction of fish being age group L for species k , their meanings, multipliers used to raise to total (TL,k) and the suitable sampling scheme. Variance formulas are also given. The variance of r3 and r6 were used in cost analysis for sample allocation. Doubt summations ΣΣ sums over i,j. Single summation Σ sums over i or j.

Ratio estimates	meaning	multiplier(F)	Sampling scheme
$r1 = \frac{\Sigma\Sigma y_{ijkL}}{\Sigma\Sigma x_{ijk}}$	no of fish per gram	Total landings(W_{0k})	SRS
$r2 = \frac{\Sigma M_{ik}(\Sigma y_{ijkL}/m_i)}{\Sigma M_{ik}}$	no of fish per sample	Total poss. samples(M_{0k})	SRS
$r3 = \frac{\Sigma M_{ik}(\Sigma y_{ijkL}/m_i)}{\Sigma M_{ik}(\Sigma x_{ijk}/m_i)}$	no of fish per gram	W_{0k}	SRS
$r4 = \frac{\frac{\Sigma m_i M_{ik}}{M_{0k}} \frac{1}{z_i} (\Sigma y_{ijkL}/m_i)}{\Sigma m_i}$	no of fish per sample	M_{0k}	PPS
$r5 = \frac{\Sigma M_{ik}(\Sigma y_{ijkL}/m_i)/z_i}{\Sigma M_{ik}/z_i}$	no of fish per sample	M_{0k}	PPS
$r6 = \frac{\Sigma M_{ik}(\Sigma y_{ijkL}/m_i)/z_i}{\Sigma M_{ik}(\Sigma x_{ijk}/m_i)/z_i}$	no of fish per gram	W_{0k}	PPS

Variance of ratio estimates (r)

$$var(r1) = \frac{(1-f)N^2}{n W_{0k}^2} \frac{\sum_i^n Y_{i\cdot kL}^2 - 2R(1)\sum_i^n (Y_{i\cdot kL} X_{i\cdot k}) + R^2(1)\sum_i^n X_{i\cdot k}^2}{(n-1)}$$

where $f = \frac{n}{N}$ $\quad Y_{i\cdot kL} = \sum_j^{m_i} Y_{ijkL}$; $X_{i\cdot k} = \sum^{m_i} X_{ijk}$

$$var(r2) = \frac{N^2(1-f)}{n M_{0k}^2} \frac{\Sigma M_{ik}^2 (\bar{Y}_{i\cdot kL} - R(1))^2}{n-1} + \frac{N}{n M_{0k}^2} \sum_i^n \frac{M_{ik}(1-f_{2i}) A_{ikL}^2}{m_i}$$

where $A_{ikL}^2 = \Sigma (Y_{ijkL} - \bar{Y}_{i\cdot kL})^2/(m_i - 1)$; $f_{2i} = m_i/M_i$

$$var(r3) = \frac{N^2(1-f)}{n W_{0k}^2} \frac{\Sigma M_{ik}^2 (\bar{Y}_{i\cdot kL} - R(1)\bar{X}_{i\cdot k})^2}{n-1} + \frac{N}{n W_{0k}^2} \sum_{i=1}^n \frac{M_{ik}^2 (1-f_{2i}) A_{ikL}^2}{m_i} \doteq \frac{N^2}{n W_{0k}^2}\left(A_1^2 + \frac{A_2^2}{m}\right)$$

where $A_{ikL}^2 = \sum_j^{m_i} [(Y_{ijkL} - R(1) X_{ijk}) - (\bar{y}_{i\cdot kL} - R(1)\cdot \bar{X}_{i\cdot k})]^2/(m_i - 1)$

$$var(r4) = \left[\frac{A_1^2}{n} + \frac{M_{0k}}{n(n-1)} \sum_i^n (m_i - 1) \frac{A_{i2}^2}{m_i} - \frac{M_{0k}^2}{n} \Sigma f_i A_i^2 / M_{ik}\right] / M_{0k}^2$$

where $A_1^2 = \left\{ \sum^n m_i M_{0k}^2 \left(\frac{M_{ik}}{M_{0k}} \frac{1}{f_i} \bar{y}_{i\cdot kL} - R(2)\right)^2 \right\} / (n-1)$

Table 3. cont'd

$$\mathcal{A}_i^2 = \left(\frac{M_{ik}}{M_{0k}} \frac{1}{\bar{z}_i}\right)^2 \sum_{j=1}^{m_i} \left(y_{ijkL} - \bar{y}_{i\cdot kL}\right)^2 \Big/ (m_i - 1)$$

$$\text{var}(r5) = \frac{1}{n(n-1) M_{0k}^2} \sum_{i=1}^{n} \frac{M_{ik}^2}{\bar{z}_i^2} \left(\bar{y}_{i\cdot kL} - R(2)\right)^2$$

$$\text{var}(r6) = \frac{1}{n W_{0k}^2} \left\{ \frac{1}{n-1} \sum_{i}^{n} \left(\frac{M_{ik}}{\bar{z}_i}\right)^2 \left(\bar{y}_{i\cdot kL} - R(1)\, \bar{x}_{i\cdot k}\right)^2 + \frac{1}{n-1} \sum_{i=1}^{n} \left(\frac{M_{ik}}{\bar{z}_i}\right)^2 (1 - f_i) \frac{\mathcal{A}_{ikL}^2}{m_i} \right\}$$

$$\doteq \frac{1}{n W_{0k}^2} \left\{ \mathcal{A}_1^2 + \frac{1}{m} \mathcal{A}_2^2 \right\} \quad \text{where } \mathcal{A}_2^2 = \frac{1}{n-1} \sum_{i=1}^{n} \left(\frac{M_{ik}}{\bar{z}_i}\right)^2 (1 - f_i) \mathcal{A}_{ikL}^2$$

Total number of fish of age group L for species k:

$Y_{Lk} = r \times F$
$\text{var}(Y_{Lk}) = \text{var}(r) \times F^2$

For NOTATIONS, see TEXT.

Table 4. Sample allocation for age composition for Pacific mackerel based on 1986 data and Jack mackerel based on 1982 data. c1 is the cost of visiting a boat, c2 is the cost of processing a sample, and c is the total money available. The entries are number of samples per boat (m) in the first row and number of boats to be sampled (n) in the second row for each year class(YC). r6 is the ratio estimate.

Pacific mackerel

STRATUM:	1						
c1/c2 =	0.5	1.0	2.0	4.0	8.0	16.0	
YC=80							
	2	3	4	5	7	9	m
c/c2=50	25	16	10	7	4	3	n
100	50	32	20	13	8	5	n
YC=81							
	4	5	7	10	13	19	m
c/c2=50	14	9	6	4	3	2	n
100	27	18	12	8	5	3	n
YC=82							
	2	3	4	6	8	11	m
c/c2=50	21	14	9	6	4	2	n
100	41	27	18	11	7	4	n
YC=83							
	1	2	2	3	4	6	m
c/c2=50	35	22	13	8	5	3	n
100	69	43	26	15	9	5	n
YC=84							
	1	1	2	2	3	4	m
c/c2=50	45	27	16	9	5	3	n
100	89	53	31	18	10	6	n
YC =85	no data						
STRATUM:	2						
YC=80							
	2	2	3	4	5	8	m
c/c2=50	29	19	12	7	4	3	n
100	58	37	23	14	8	5	n
YC=81							
	3	3	5	6	9	12	m
c/c2=50	20	13	9	6	4	2	n
100	40	26	17	11	7	4	n

Table 4 cont'ed

c1/c2 =	0.5	1.0	2.0	4.0	8.0	16.0	
YC=82							
	2	2	3	4	6	8	m
c/c2=50	29	18	12	7	4	3	n
100	57	36	23	14	8	5	n
YC=83							
	2	2	3	4	5	7	m
c/c2=50	32	20	12	7	5	3	n
100	63	39	24	14	9	5	n
YC=84							
	1	2	2	3	4	5	m
c/c2=50	38	23	14	8	5	3	n
100	76	46	28	16	9	5	n
YC=85							
	1	1	1	1	2	2	m
c/c2=50	61	35	19	11	6	3	n
100	121	69	38	21	11	6	n
STRATUM:		3					
YC=80							
	2	2	3	3	5	6	m
c/c2=50	33	21	13	8	5	3	n
100	66	41	25	15	9	5	n
YC=81							
	2	2	3	4	6	8	m
c/c2=50	29	18	11	7	4	3	n
100	57	36	22	14	8	5	n
YC=82							
	2	2	3	3	5	6	m
c/c2=50	33	21	13	8	5	3	n
100	66	41	25	15	9	5	n

Table 4 cont'ed

c1/c2 =	0.5	1.0	2.0	4.0	8.0	16.0	
YC=83							
	1	2	2	3	4	6	m
c/c2=50	36	22	14	8	5	3	n
100	72	44	27	16	9	5	n
YC=84							
	2	2	3	4	6	8	m
c/c2=50	29	18	12	7	4	3	n
100	57	36	23	14	8	5	n
YC=85							
	1	2	2	3	4	6	m
c/c2=50	36	22	14	8	5	3	n
100	71	44	27	16	9	5	n

Jack mackerel

c1/c2 =	0.5	1.0	2.0	4.0	8.0	16.0	
STRATUM:		1					
YC=76							
	1	1	2	2	3	4	m
c/c2=50	45	28	16	9	5	3	n
100	93	54	31	18	10	6	n
YC=77							
	1	2	2	3	4	6	m
c/c2=50	36	22	14	8	5	3	n
100	71	44	27	16	9	5	n
YC=78							
	1	2	2	3	4	6	m
c/c2=50	35	22	13	8	5	3	n
100	67	43	26	15	9	5	n
YC=79							
	2	2	3	3	5	6	m
c/c2=50	33	21	13	8	5	3	n
100	66	41	25	15	9	5	n

Table 4 cont'ed

c1/c2 =	0.5	1.0	2.0	4.0	8.0	16.0	
YC=80							
	2	2	3	4	6	8	m
c/c2=50	27	18	11	7	4	3	n
100	54	35	22	13	8	5	n
YC=81							
	3	3	5	6	9	12	m
	20	13	9	6	4	2	n
	39	26	17	11	7	4	n

STRATUM: 2

YC=76							
	5	7	9	13	18	25	m
c/c2=50	11	7	5	4	2	2	n
100	21	14	10	7	4	3	n
YC=77							
	3	4	5	7	9	13	m
c/c2=50	19	13	8	5	3	2	n
100	37	25	16	10	6	4	n
YC=78							
	2	2	3	4	5	7	m
	30	19	12	9	4	3	n
	59	38	23	14	8	5	n
YC=79							
	2	2	3	3	5	6	m
	33	21	13	8	5	3	n
	66	42	25	15	9	5	n
YC=80							
	5	6	9	12	17	23	m
c/c2=50	12	8	5	4	3	2	n
100	23	15	10	7	5	3	n
YC=81							
	1	1	1	1	1	2	m
c/c2=50	73	40	22	12	6	3	n
100	146	79	43	23	12	6	n

STRATUM: 3

YC=76
YC=77 no data
YC=78

Table 4 cont'ed

c1/c2 =	0.5	1.0	2.0	4.0	8.0	16.0	
YC=79							
	1	2	2	3	4	5	m
c/c2=50	39	24	14	9	5	3	n
100	78	45	28	17	9	5	n
YC=80							
	4	5	8	10	15	20	m
c/c2=50	13	9	6	4	3	2	n
100	25	17	12	8	5	3	n
YC=81							
	1	1	1	2	2	3	m
c/c2=50	51	30	17	10	6	3	n
100	101	60	34	19	11	6	n

Table 5. Comparison between visual estimates(VE) and bucket estimates(BE) of species composition: Paired t test for checking the possible bias of jack mackerel(JM) and Pacific mackerel(PM) where d=VE - BE and the distribution of mean and standard deviation of visual estimates by 10 equal intervals of age composition from bucket estimates. The data are expressed in percent.

Paired t test:

		1985	1986
JM	mean(d)	0.50	-0.39
	se	1.11	1.11
	n	208	217
	t	0.45	-0.35
PM	mean(d)	0.62	1.23
	se	0.99	1.05
	n	214	227
	t	0.63	1.17

Mean and standard deviation (STD DEV) of VE by percent intervals:

1985
Jack mackerel

	BE		VE				
INTERVAL	MEAN	STD DEV	MEAN	STD DEV	MIN	MAX	COUNT
0 -10	3.73	2.92	7.09	15.94	0	100	64
-20	15.08	2.77	15.73	12.66	2	55	23
-30	24.46	3.01	23.76	13.31	0	40	13
-40	35.21	2.57	46.50	23.69	0	85	14
-50	45.40	3.21	39.59	21.74	4	95	22
-60	56.20	3.32	53.33	12.27	35	80	15
-70	65.50	2.50	63.50	9.48	45	80	14
-80	75	3.02	60	26.04	0	80	8
-90	85.77	3.30	86.22	17.92	40	100	9
91-100	96.61	2.31	98.11	5.90	70	100	26
ALL	38.65	33.25	39.14	35.28	0	100	208

Table 5 cont'ed

Pacific mackerel

	BE		VE				
INTER	MEAN	STD DEV	MEAN	STD DEV	MIN	MAX	COUNT
0 -10	3.80	3.15	4.90	9.07	0	30	10
-20	14.57	2.44	19.57	19.78	2	60	7
-30	24.87	2.85	37.75	26.80	20	100	8
-40	35.17	2.94	36.53	13.31	10	65	17
-50	45.35	3.65	48.29	14.31	5	70	17
-60	54.75	2.72	62.12	17.64	40	95	16
-70	63.93	2.76	55	23.59	15	100	16
-80	86.14	2.67	76.35	14.62	45	98	17
-90	85.96	2.83	86.96	12.61	45	100	29
91-100	96.91	2.45	95.97	8.37	45	100	77
ALL	69.42	29.24	70.05	30.70	0	100	214

1986

Jack mackerel

	BE		VE				
INTERVAL	MEAN	STD DEV	MEAN	STD DEV	MIN	MAX	COUNT
0-10	4.09	2.72	3.37	4.44	0	30	54
-20	15.07	3.36	11.71	8.24	2	30	14
-30	25.95	2.52	32.91	20.86	5	77	24
-40	35.60	2.83	37.86	15.26	10	84	30
-50	46.46	3.04	44.42	16.47	5	90	26
-60	55.51	3.14	56.69	19.53	20	98	29
-70	65.11	3.08	63.44	18.86	15	85	18
-80	74.83	2.58	64.83	24.37	15	92	12
-90	84.28	3.14	73.85	32.95	1	98	7
91-100	94.66	1.52	97.33	2.08	95	99	3
ALL	36.33	25.37	35.94	28.90	0	99	217

Table 5 cont'ed

Pacific mackerel

	BE		VE				
INTERVAL	MEAN	STD DEV	MEAN	STD DEV	MIN	MAX	COUNT
0 -10	6.80	2.77	5.40	5.59	1	15	5
-20	16	2.88	27.71	33.63	2	99	7
-30	26.17	2.89	36.52	23.79	10	85	17
-40	36.88	2.22	33.27	14.64	15	75	18
-50	45.44	2.92	47.50	18.41	2	85	34
-60	55.34	3.14	53.80	16.96	10	95	26
-70	65.07	2.97	62.51	17.30	15	89	27
-80	74.90	3.20	77.59	16.53	20	95	22
-90	86.46	3.07	89.15	9.31	66	98	13
91-100	95.50	2.65	96.17	4.61	70	100	58
ALL	63.02	25.93	64.26	29.32	1	100	227

Table 6. Sample allocation for estimating landing of Pacific mackerel (species composition) based on 1986 data. The symbol, c1, is the cost of visiting a boat, c2 is the cost of processing a sample, and c is the total money available. The entries are number of samples per boat (m) and number of boats to be sampled (n). The strata (5000 tons) are from the 1986 fleet data set.

c1/c2	0.5	1.0	2.0	4.0	8.0	16.0	
Stratum 1	1	1	1	1	2	2	m
c/c2=50	124	36	20	11	6	3	n
100	27	71	39	21	11	6	n
Stratum 2	1	1	2	2	3	3	m
c/c2=50	49	29	17	10	5	3	n
100	98	58	33	19	10	6	n
Stratum 3	1	1	1	2	2	3	m
c/c2=50	58	34	19	10	6	3	n
100	116	67	37	20	11	6	n
Stratum 4	1	1	1	1	1	1	m
c/c2=50	75	41	22	12	6	3	n
100	150	81	43	23	12	6	n
Stratum 5	1	1	1	1	1	1	m
c/c2=50	73	40	22	12	6	3	n
100	146	80	43	23	12	6	n
Stratum 6	1	1	1	2	2	3	m
c/c2=50	52	31	18	10	6	3	n
100	104	61	35	19	11	6	n
Stratum 7	1	1	1	1	1	1	m
c/c2=50	75	41	22	12	6	3	n
100	149	81	43	23	12	6	n
Stratum 8	1	1	1	1	1	2	m
c/c2=50	60	34	19	11	6	3	n
100	120	68	38	21	11	6	n

Table 7. The ratio of number of boats sampled (n1)for species composition to the number of boats sampled (n2) for age composition for various values of ra(CV) which measures the additional relative variance contributed by the species composition to the total variance of age composition. n1/n2 was computed for each year class by stratum based on 1986 data.The ratio CV1/CV2 is a special case of ra(CV) when n1=n2

Stratum 1					
Year	ra(CV)				CV1/CV2
class	0.05	0.10	0.30	0.50	
80	24.8	12.4	4.13	2.48	1.24
81	77.6	38.8	12.9	7.76	3.88
82	32.6	16.3	5.43	3.26	1.63
83	8.0	4.0	1.33	0.80	0.40
84	2.6	1.3	0.43	0.26	0.13
Stratum 2					
Year	ra(CV)				
class	0.05	0.10	0.30	0.50	
80	23.00	11.5	3.83	2.30	1.15
81	174.2	87.1	29.03	17.42	8.71
82	58.6	29.3	9.77	5.86	2.93
83	26.96	13.48	4.49	2.69	1.35
84	33.8	16.9	5.63	3.38	1.69
85	8.38	4.19	1.40	0.84	0.42
Stratum 3					
Year	ra(CV)				
class	0.05	0.10	0.30	0.50	
80	29.48	14.74	4.90	2.95	1.47
81	61.74	30.87	10.29	6.17	3.09
82	30.5	15.25	5.08	3.05	1.53
83	13.8	6.92	2.30	1.38	0.69
84	67.4	33.70	11.23	6.74	3.37
85	56.3	28.15	9.38	5.63	2.82

Table 8. Percentage of landings within species related to different species composition. The headers are the percentage of fish being one species. PM is Pacific mackerel, JM is jack mackerel, and n is number of boat loads sampled.

1985	1-4	5-10	11-20	21-50	51+	Total
PM						
Bucket	0.08	0.1	0.3	5.79	93.7	100
n	15	8	8	48	356	435
Visual	0.23	0.16	0.36	6.1	93.15	100
n	10	9	10	67	497	593
JM						
Bucket	1.2	2.1	5.3	28.0	63.4	100
n	65	34	29	57	85	270
Visual	0.89	2.9	4.2	26.0	66.01	100
n	51	50	26	63	119	309
Sardine						
Bucket	31	31	24	14	0	100
n	98	27	13	5	0	143
Visual	21	39	28	8.8	3.2	100
n	72	42	11	3	2	130

1986	1-4	5-10	11-20	21-50	51+	Total
PM						
Bucket	0.03	0.08	0.5	12.9	86.45	100
n	4	4	8	72	226	314
Visual	0.06	0.17	0.68	5.4	93.7	100
n	19	16	22	69	591	717
JM						
Bucket	0.84	2.35	3.2	39.8	53.8	100
n	38	27	17	82	75	239
Visual	1.0	2.5	5.0	32.9	58.5	100
n	68	44	44	121	123	400
Sardine						
Bucket	25.6	23.6	13.9	36.9	0	100
n	69	17	7	7	0	100
Visual	36.7	43.6	13.2	6.5	0	100
n	135	47	10	2	0	194

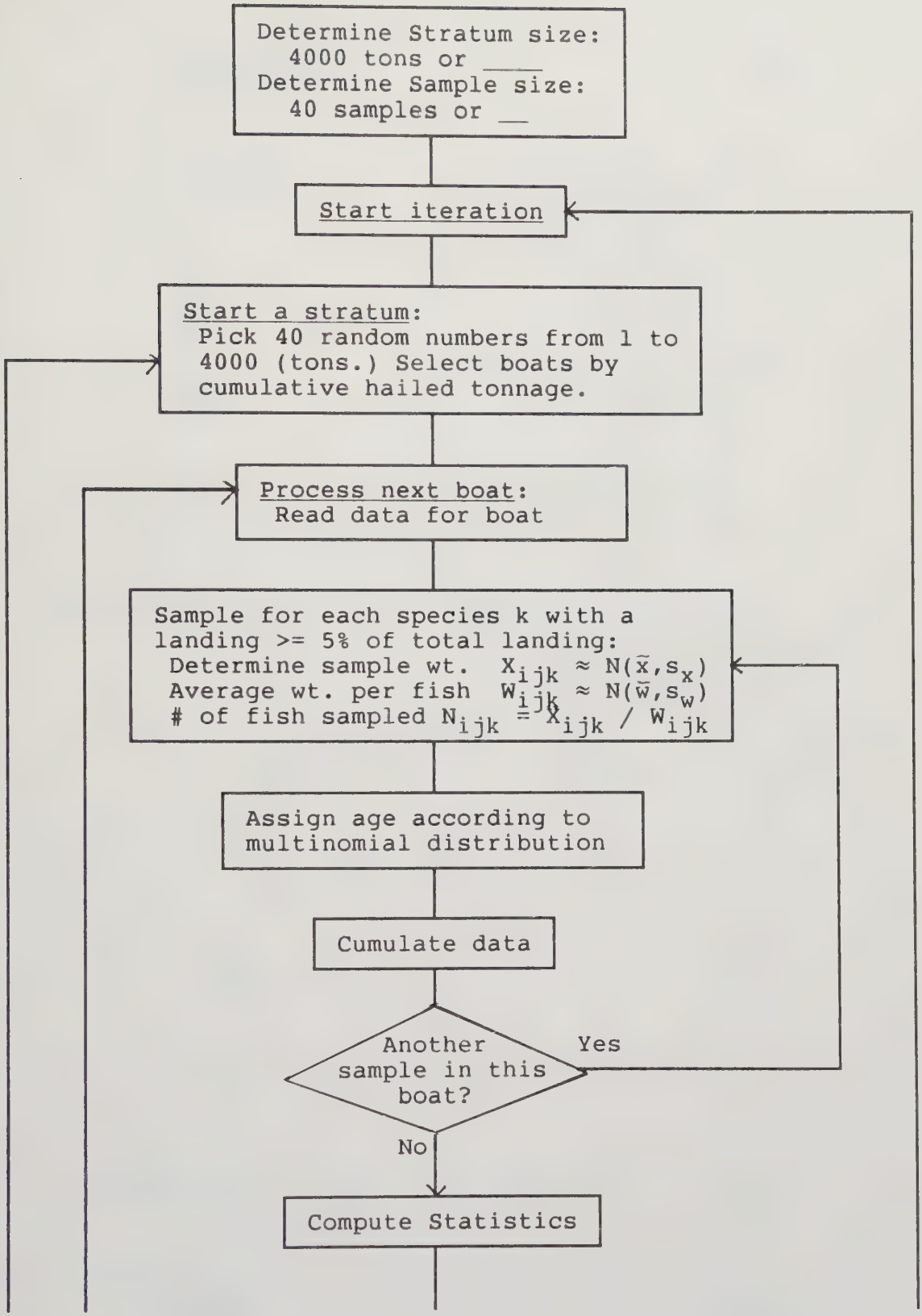
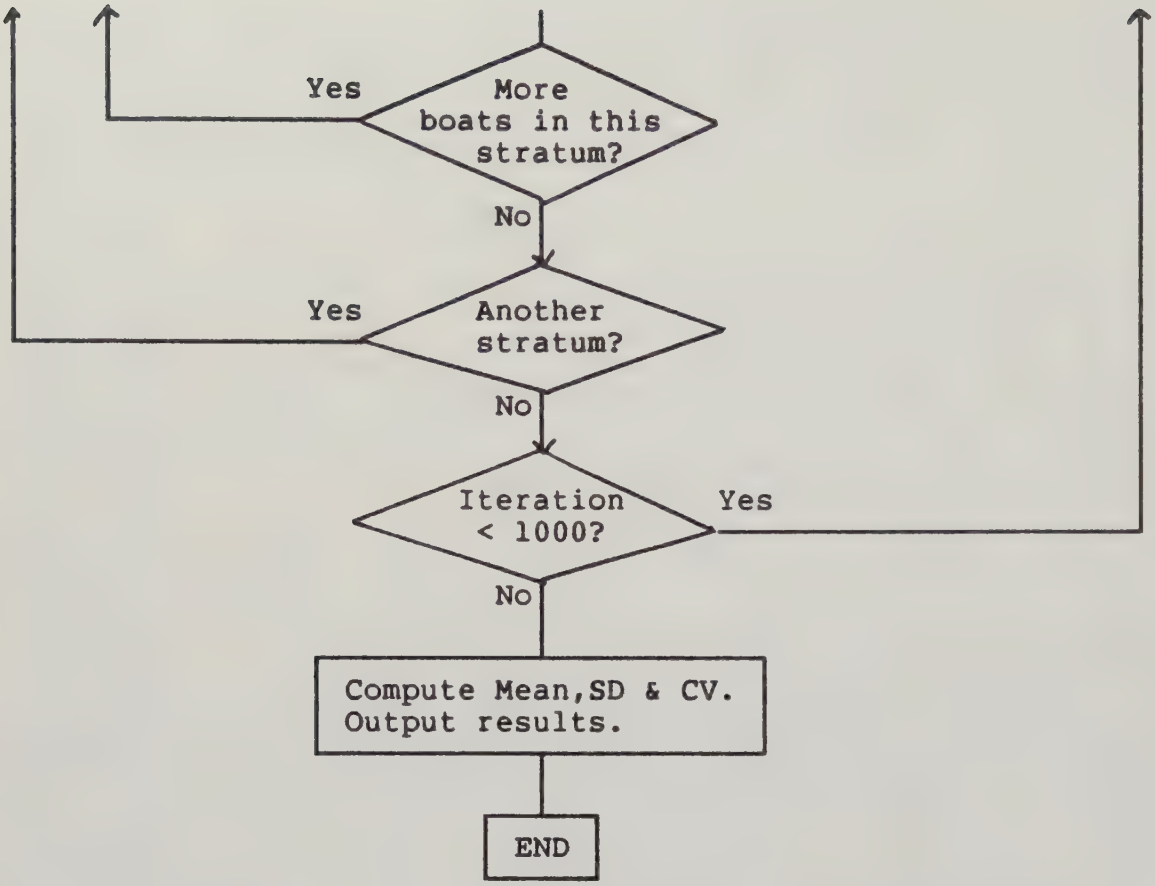

Determine Stratum size:
4000 tons or ____
Determine Sample size:
40 samples or __
Start iteration
Start a stratum:
Pick 40 random numbers from 1 to 4000 (tons.) Select boats by cumulative hailed tonnage.
Process next boat:
Read data for boat
Sample for each species k with a landing >= 5% of total landing:
Determine sample wt. $X_{ijk} \approx N(\bar{x}, s_x)$
Average wt. per fish $W_{ijk} \approx N(\bar{w}, s_w)$
# of fish sampled $N_{ijk} = X_{ijk} / W_{ijk}$
Assign age according to multinomial distribution
Cumulate data
Another sample in this boat?
Yes
No
Compute Statistics

Figure 1. Flow chart for simulation procedure for the proportion to size sampling scheme.


More boats in this stratum?
Yes
No
Another stratum?
Yes
No
Iteration < 1000?
Yes
No
Compute Mean,SD & CV. Output results.
END

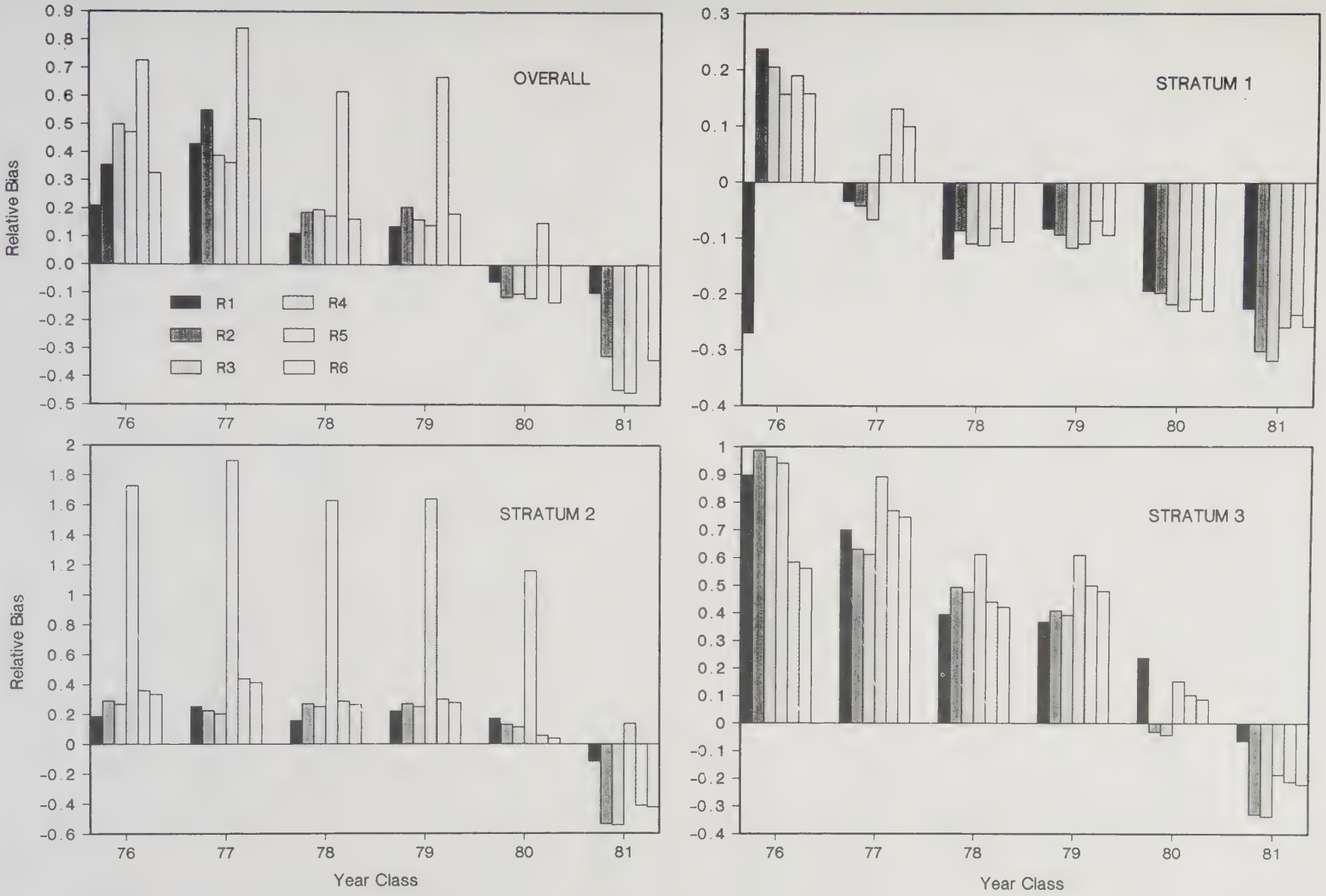


Figure 2a. The relative bias (RB) of six ratio estimates of age composition for Pacific mackerel at sample size =40 for each year class by stratum based on 1982 data under PPS.

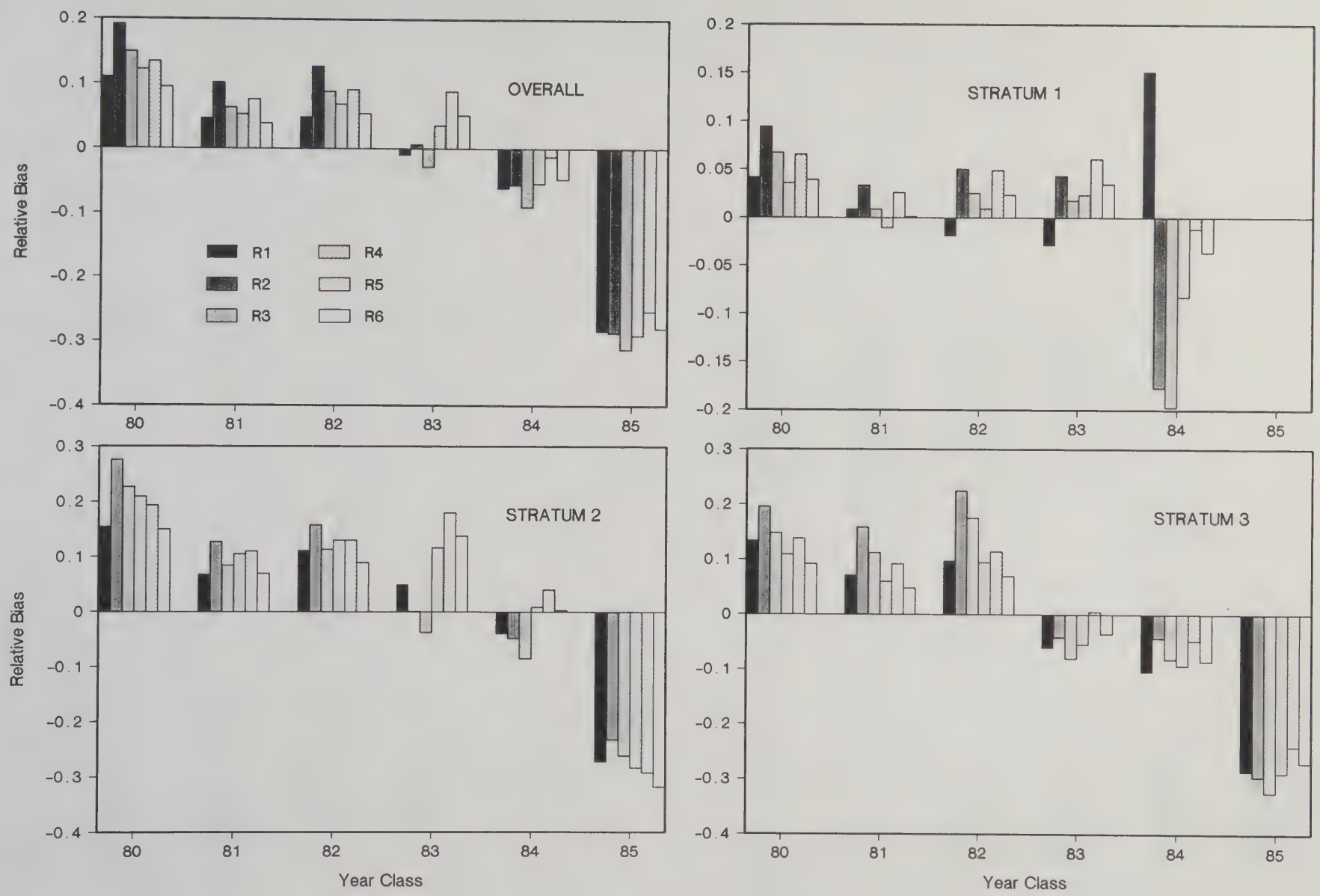


Figure 2b. The relative bias (RB) of six ratio estimates of age composition for Pacific mackerel at sample size =40 for each year class by stratum based on 1986 data under PPS.

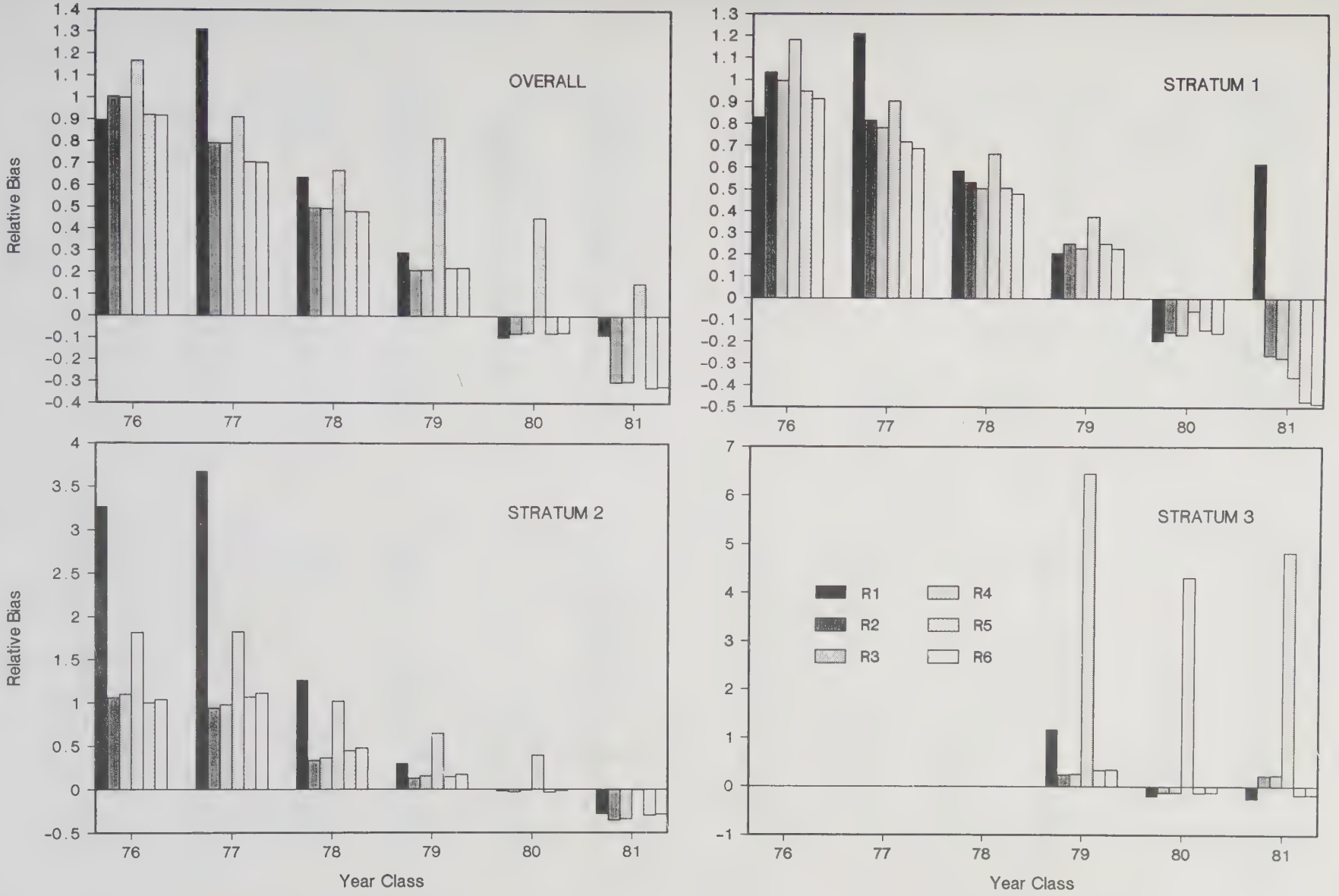


Figure 3. The relative bias (RB) of six ratio estimates of age composition for Jack mackerel at sample size =40 for each year class by stratum based on 1982 data under PPS.

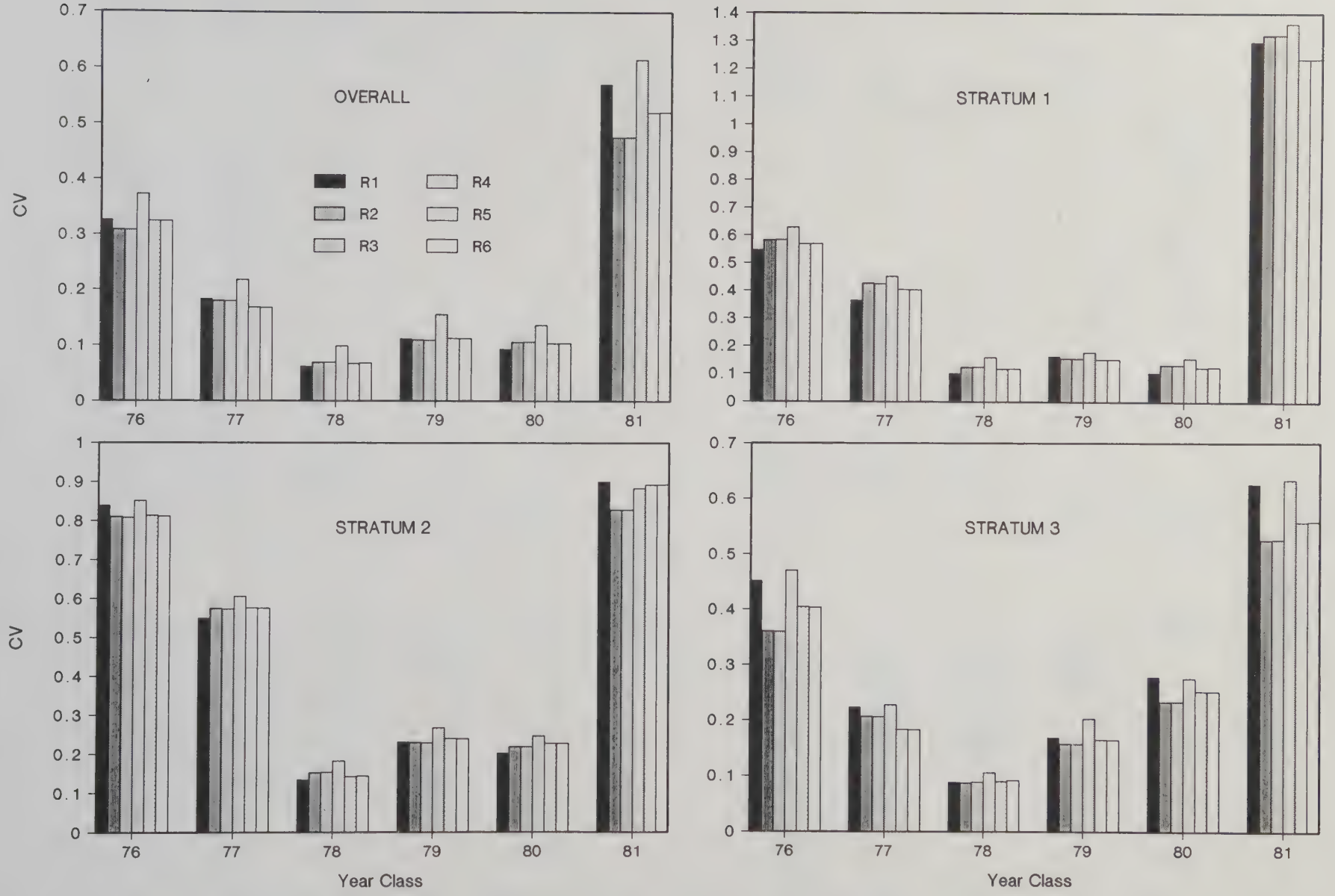


Figure 4a. The coefficient of variation (CV) of six ratio estimates of age composition for Pacific mackerel at sample size =40 for each year class by stratum for 1982 under PPS.

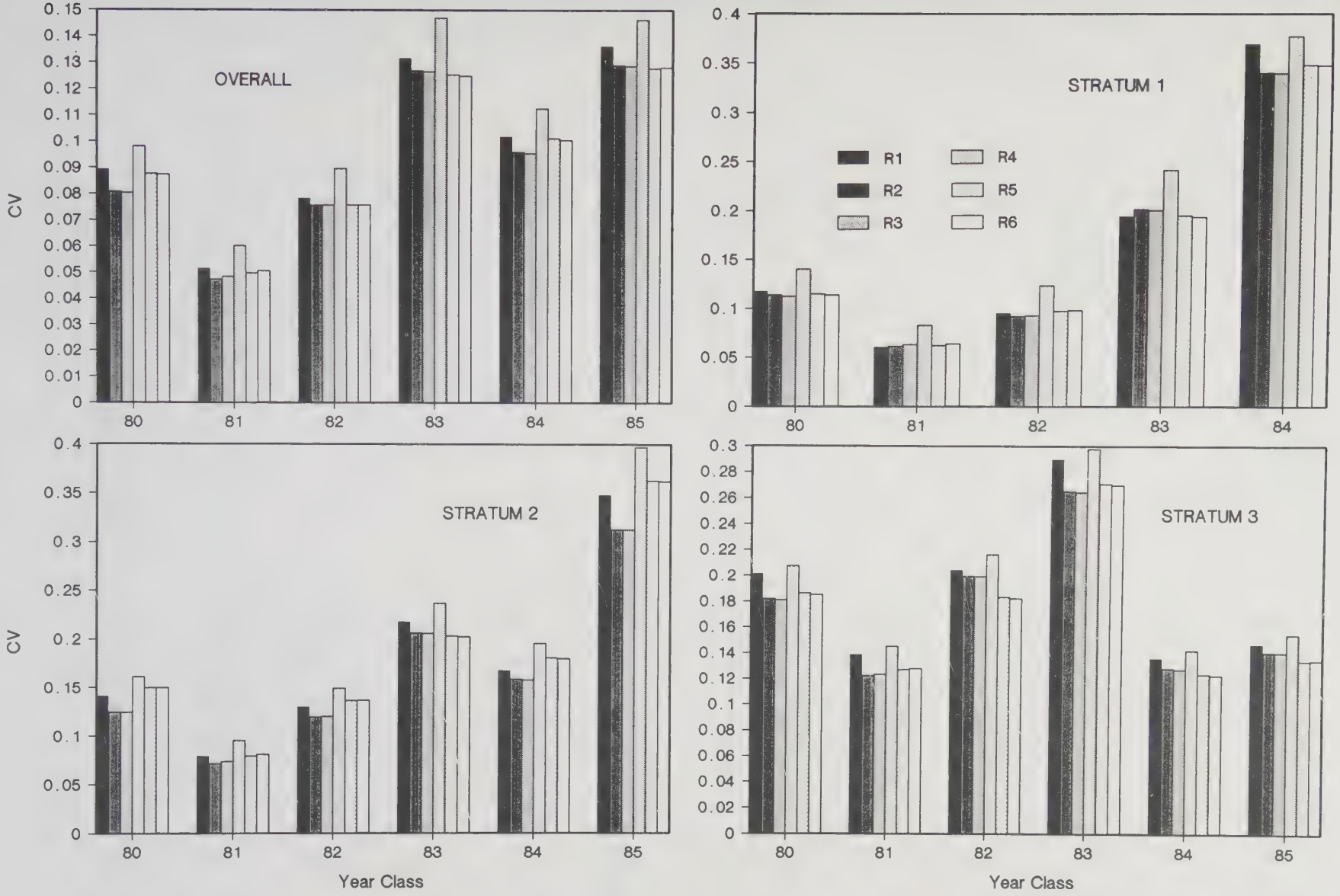


Figure 4b. The coefficient of variation (CV) of six ratio estimates of age composition for Pacific mackerel at sample size =40 for each year class by stratum for 1986 under PPS.

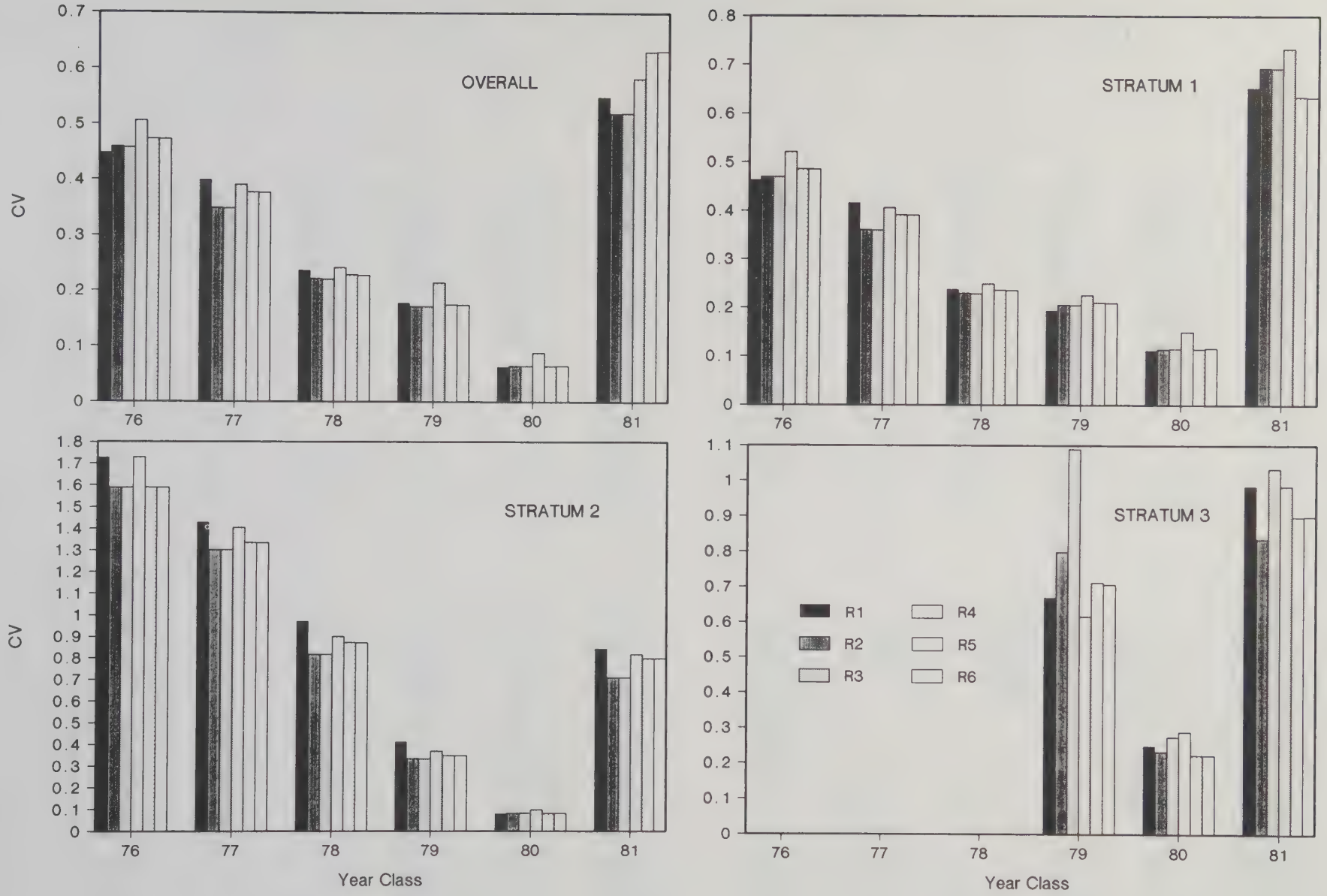


Figure 5. The coefficient of variation (CV) of six ratio estimates of age composition for Jack mackerel at sample size =40 for each year class by stratum for 1982 under PPS.

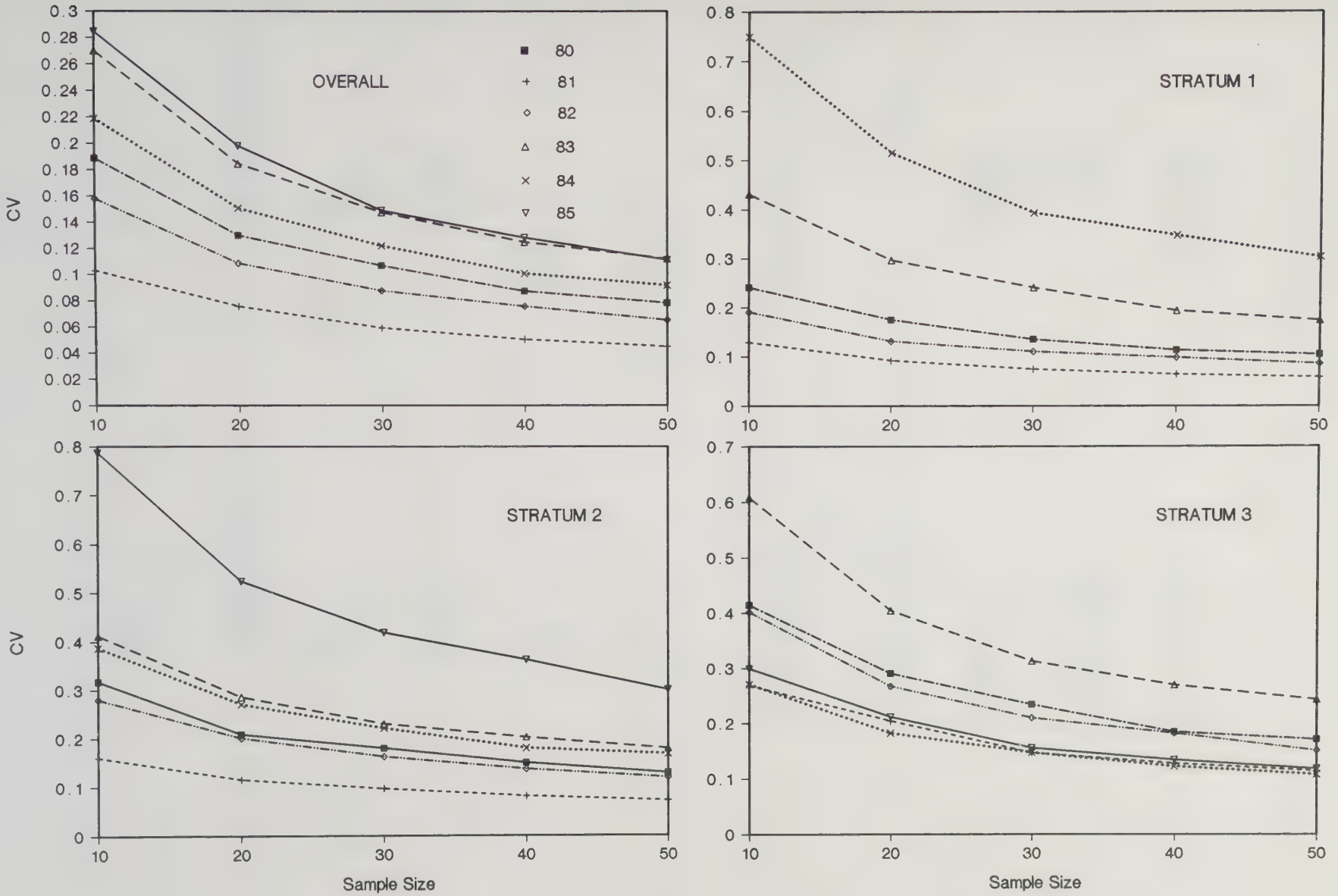


Figure 6. CV(r6) of Pacific mackerel at various sample size based on 1986 data under PPS.

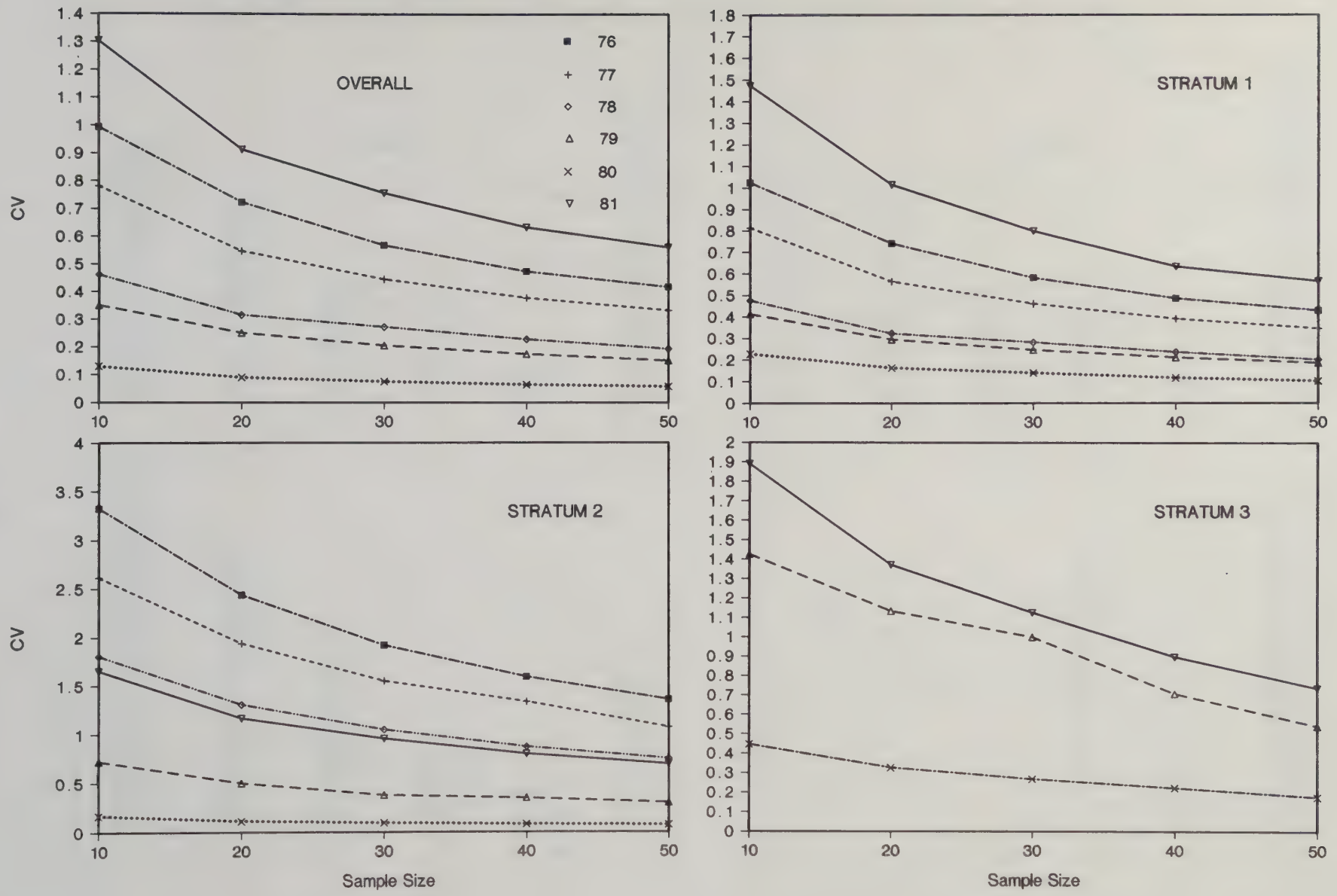


Figure 7. CV(r6) of Jack mackerel at various sample size based on 1982 data under PPS.

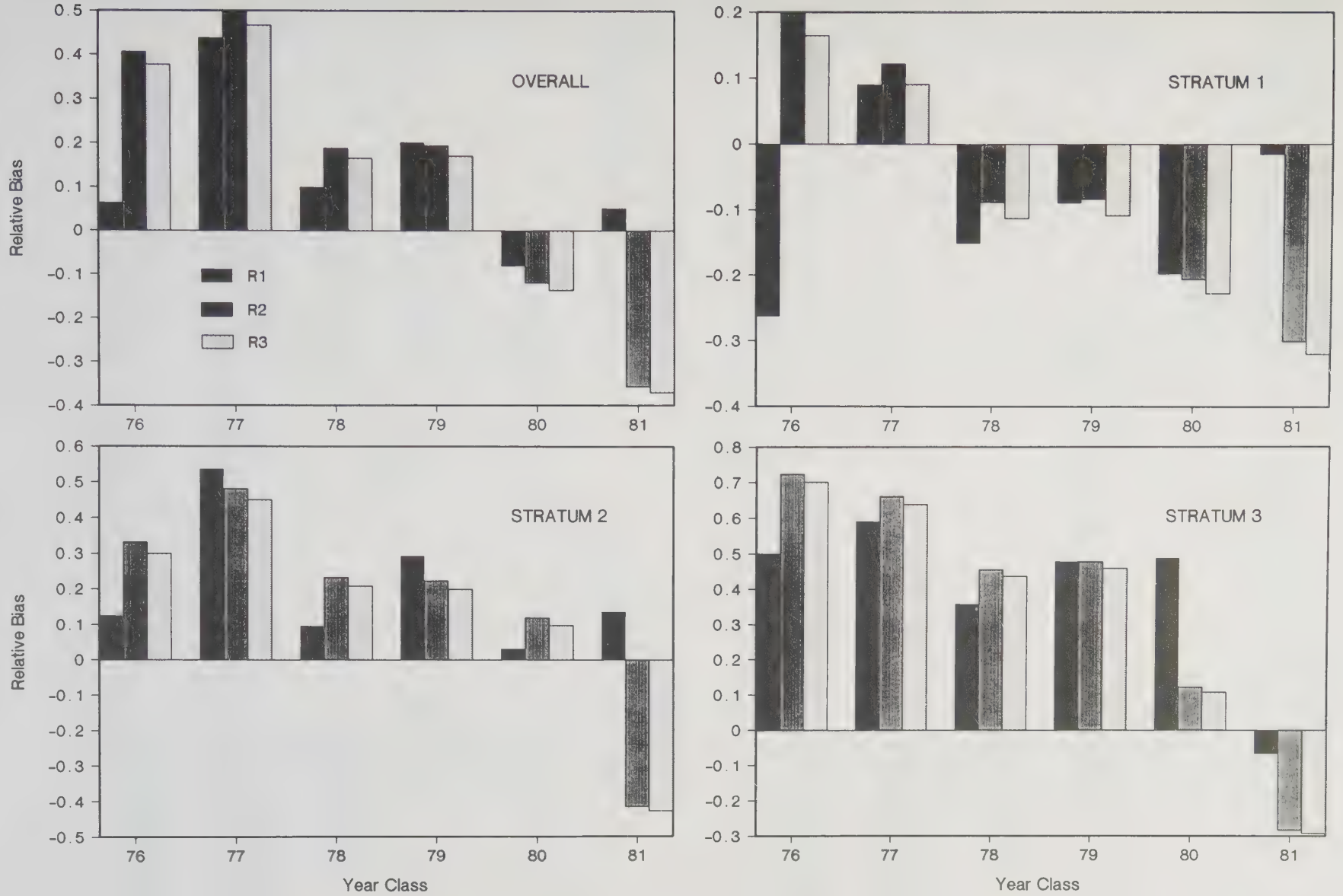


Figure 8. The relative bias (RB) of six ratio estimates of age composition for Pacific mackerel at sample size =40 for each year class by stratum based on 1982 data under SRS.

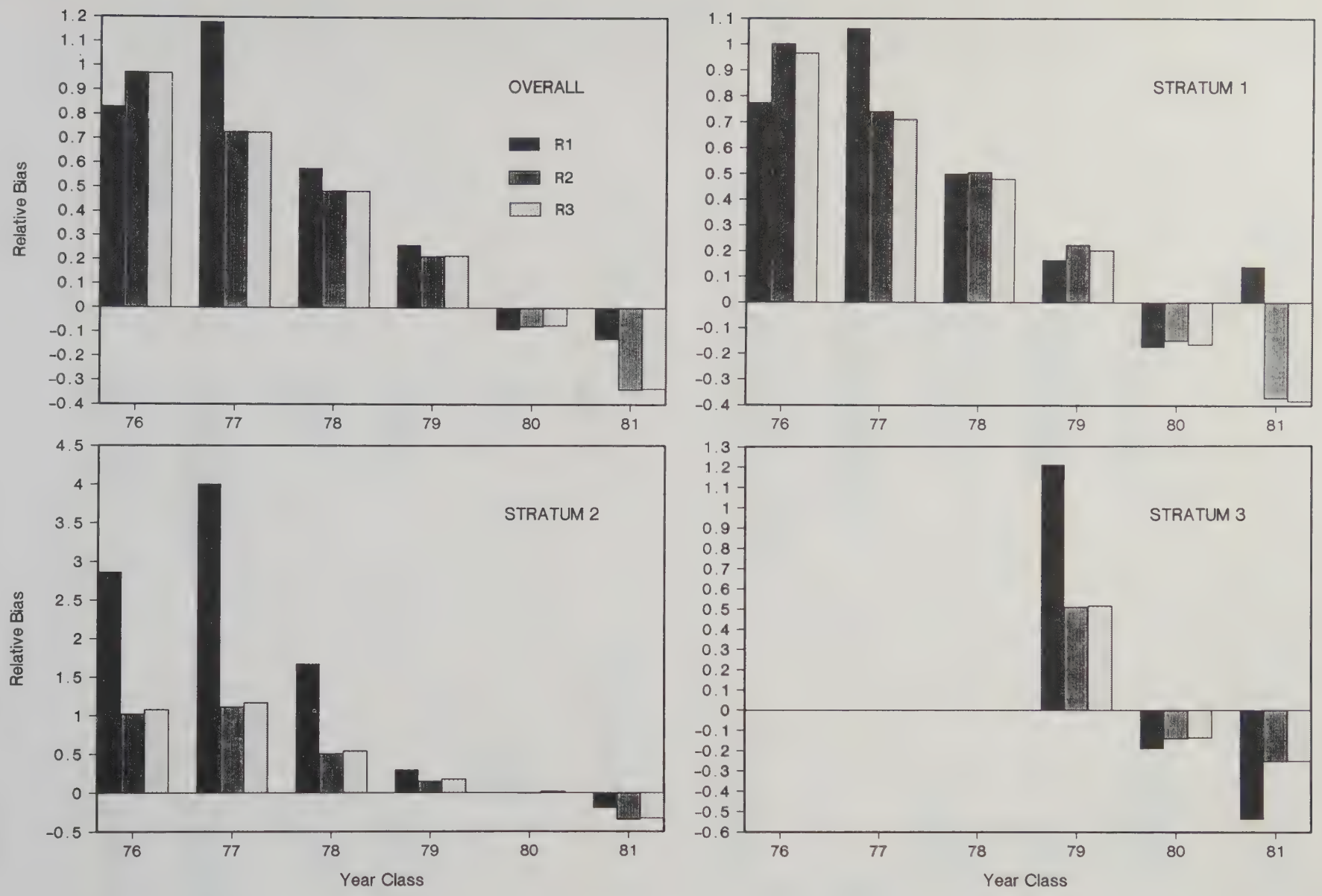


Figure 9. The relative bias (RB) of six ratio estimates of age composition for Jack mackerel at sample size =40 for each year class by stratum based on 1982 data under SRS.

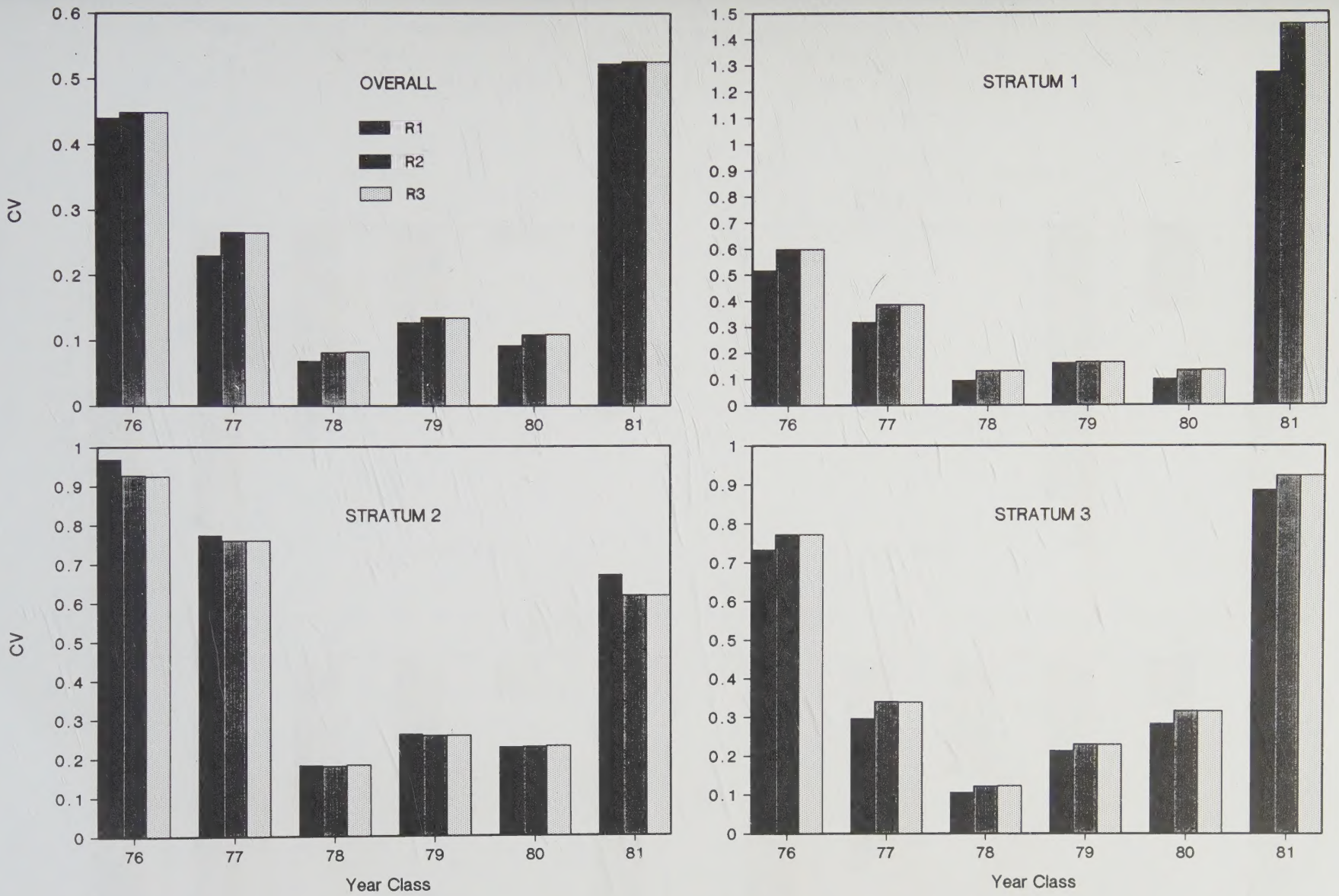


Figure 10. The coefficient of variation (CV) of six ratio estimates of age composition for Pacific mackerel at sample size =40 for each year class by stratum for 1982 under SRS.

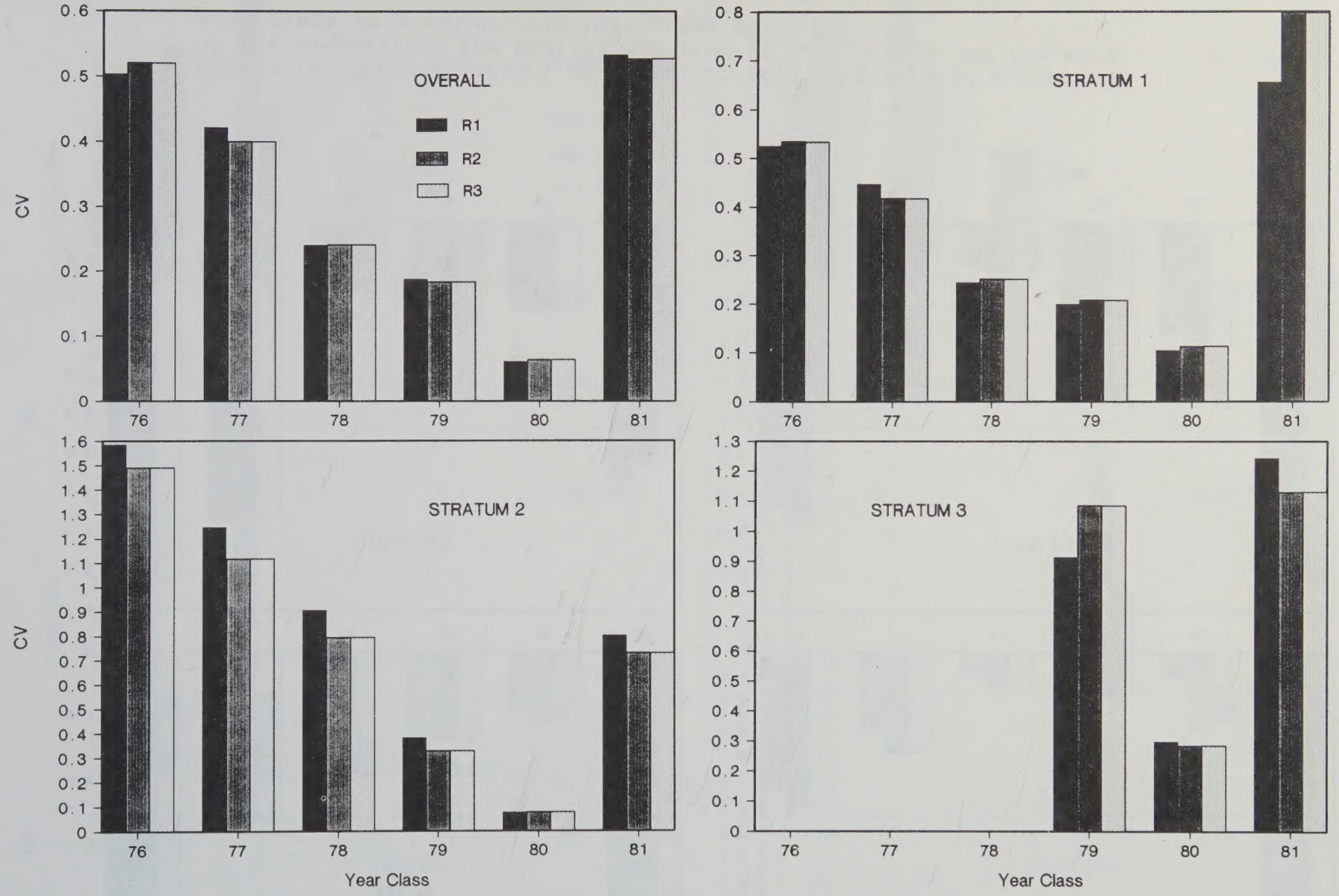


Figure 11. The coefficient of variation (CV) of six ratio estimates of age composition for Jack mackerel at sample size =40 for each year class by stratum for 1982 under SRS.